Grau en Enginyeria en Geoinformació i Geomàtica

Photogrammetric reconstruction of the Roman ruins of *Llosa de Cambrils.*

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Introduction.

The advances in technology are evolving at a really fast pace in regards of the techniques we used to use in the past decades. Such advances have been even more radical in the fields of geomatics that have reached such perfectioning limits only imaginable if coming from great revolutions, both in the scientific and technological fields.

The new technologies, that were only used in a concrete field of work in the past, are now being used in other fields of work that were once unthinkable. Science based in ofimatica has made this progress easier by making these processes, once slow and expensive, much easier at the same time it has improved their results' precision. Thus obtaining an optimization and optimization that exponentially improved the topographic procedures and, along with it, of many other disciplines of the technologic and scientific side.

All these improvements are being applied in the fields of topography, engineery, architecture and construction between many others. Technologies such as the 3D viewing of an object, thermographic cameras, along with all kinds of measurers, calculus programs, etc. that have spurred the worker's productivity along with the companies' itself, with the valuable add up of the improvement of the quality of human work.

The Topography in concrete, this improvements, had made us go from chains, compasses, displacements and plumbs, to handling GPS's, 3D digital scanners and computer measurements along with the evolution of electronic devices. Thanks to the latter, such simple task as to get angles, is now way faster, more effective, and more precise than it was back in time. With the actual total stations a huge improvement has been made in the angular reading and distance reading, not forgetting the motorized point stakeout stations along with the robotized, that by using a search and following system for a prism allows the data collection without an operator handling the station. Without further ado to get even deeper inside the history of the evolution of the topographic measurement apparels, we cannot leave the development of the Global Positioning Systems without a mention. They have given us access to the real-time data collection with the Geographical Information Systems along with images captured from satellites giving way to new techniques in the remote sensing field. With everything said above, there is no doubt that we have greatly widened the old traditional limits that the measurement instruments and cartography itself once had.

But, despite all these improvements and new technologies, along with the great changes in the applied methods used. The traditional concept of Topography still remains the same it was in Egiotian times. It is also curious how iside the same field it is still looked after a more "artisan" way of work, especially in the tasks of heritage architectural surveys, that would be needed for any project of subsidence, reform or cataloging, which is precisely the objective of this work. The objective of wich is the reconstruction of 3D model of the Roman ruins of La Llosa of Cambrils.

Paper, pencil, and measuring tape are still considered useful field tools along with the photographic camera (to check the sketch). Photography and measuring tools converge in the field of photogrammetry with which we get the real magnitude represented in the photographic images allowing us to measure real distances over the graphical documentation obtained in the processing of the same. Photogrammetry has brought many advantages, especially by reducing the field work and by obtaining precise plans.

Justification and Objectives.

From the very beginning of this project I was certain that I wanted to do a photogrammetric surveying of a significant construction within my living area, the *Baix Camp.*

For its procedure and technique, it is a project that I personally find very attractive as well as I find it topographically and architectonically valuable. Furthermore, the interest it has for the heritage conservation and archaeological was an extra source of motivation and added to this project, which at first sight was only a technological procedure, a cultural aspect that was not considered at first.

Understanding photogrammetry as a tool that allows us to digitize in three dimensions an infinite number of open spaces and constructions, I feel necessary its diffusion and normalization in the fields of documentation, conservation and restoration in different areas like art, architecture, archaeology, and forest conservation, etc.

After visiting different architectonic elements of some importance in the area, like the *Casa Navàs* in Reus or the *Institut Pere Mata* in the same city, I thought it would be more interesting to make a photogrammetric reconstruction of the remains of the Roman villa of *La Llosa* in Cambrils in order to be able to study and to get to know the architecture of that time and to give the restoration team of the finding real a 3D reconstruction of the villa.

I then decided to make the reconstruction of *La Llosa* of Cambrils the main object of my project by making a 3D model using the photogrammetry technique. We pretend to verify that it is a useful tool for the surveying and analysis of the heritage. As said before, it is a Roman villa that was part of the great Tarraco in between the 1b.C. and 4a.C centuries. Because of this, we expect this work to have two parts. The first, to study the historical and architectonic side of the Roman era and the second, to study the technical aspects of photogrammetry, by taking and managing data, analyzing the results and making conclusions of them.

The main objective that we have is to obtain a 3D model of the architectonic finding of the Roman period by using photogrammetry. Related to the method used, we'll be using tools with low a low price range that will not sacrifice precision despite their difference in price with more precise and quality tools. In order to do so it will also be important to take into consideration the efficiency and effectivity when working on the terrain, getting the minimum error, with the minimum resources and the perfect weather conditions not to lose the quality we are hoping for.

Another objective in the work in hand will be to find other working field where our project could be used. It is with this that we pretend to give a photogrammetric reconstruction that will provide useful information in the studies of archaeological investigation along with architectural and historical purposes.

The will of this work also lays into deepening the used technique with different tools and systems of geographic referencing.

A derived objective of this project is to catalogate and have a 3D model to conserve/preserve the cultural heritage and to avoid loosing this finding because of natural disasters or human factors or to restore it or reconstruct it in case it happened.

Background.

Introduction to photogrammetry.

According to the American Society of Photogrammetry and Remote Sensing (ASPRS), photogrammetry is the "art, science and technology used to obtain reliable information about physical objects and of their environment through registering and measuring processes and image interpretation, radiant electromagnetic energy patterns and other phenomena".

Nowadays, any topographic surveying of a certain magnitude is made with photogrammetry techniques (aerial photographs) and, despite the fact that the concept is implicitly tied to the cartographic production, it has been used on a wider range of applications going from Photointerpretation to Remote Sensing.

According to Boneval, photogrammetry is defined as "the technique used to study and define with precision the shape, dimensions and position in space of an object, essentially using measurements made over one or many photographs of the same object".

Photogrammetry advantages:

- We obtain whole representations of the object (objective information).
- The registering is instant.
- It uses rather economic materials easily manipulable and conserved.
- There is the possibility to work with moving objects.
- The information capturing process and the following measurements do not "disturb" the studied object.
- Proportionates great performance.

Divisions in photogrammetry:

- According to the type of photography:
    - Terrestrial photogrammetry. The photography is used in a way so that the axis of the photographic camera is horizontal and parallel to the ground or terrestrial crust.
    - Aerial photogrammetry. Photographs taken from aerial vehicles; the optic axis of the photographic camera is rather perpendicular to the terrain or terrestrial crust.

- According to the method used:

Analogical photogrammetry. The precise determination of an object in space. Using aerial photographs, the analogical photogrammetry pinpoints the object's location by directly using said photographs (making stereoscopic models) by reconstructing the spatial model with optic or mechanical systems.

Analytical photogrammetry. In this case the spatial model is exclusively reconstructed by using informatics programs simulating said geometry.

Digital photogrammetry. Uses as input data the aerial photografies previously transformed to digital format, thus reconstructing the spatial model in a numeric or digital form. In this case the concepts related to digital image processing have great value.

Photogrammetry with drones.

Even if their major association is with the audiovisual sector they have turned out as a very useful tool in the field of topography and cartography, specially in the areas of 3D reconstructions and volume calculations. The volume calculations are being perfectionated with the use of drones without forgetting how much faster we can work with them.

The work progress with a drone consists in the aerial photo capture which are processed by using specific programmes in order to obtain the 3D models and orthomosaics, a few examples of these specific programmes would be Agisoft and PhotoScan (Said programs are capable of obtaining a 1cm precision in planimetry). Once we have the georeferenced, aerial, vertical, consecutive, homogeneous photographs we overlap them in order to generate a global stereoscopic photograph. Afterwards (by using the very same programmes) we obtain the camera's data calibration that allows us to know from where were the photographs taken, generating a georeferenced point cloud of the surface in study.

The advantages of using a drone in photogrammetry are:

The topographic reliance (wich is, without a doubt, the most important one).
The efficiency by obtaining millions of points (in color). Evidently the surveyed surface is better represented and is more adjusted to its reality thanks to the quantity and quality of the points obtained by the drone.
Related to the previous advantage, we must remark the visual value that its proportioned by this method.
The fieldwork is exponentially reduced which reduces this option's labor cost.

Despite all of the significant improvements in this field, we still have some limitations, on the juridical side mainly, which we have to take into account:

The flight distance is limited by the current Spanish law. Nowadays the stipulated distance is of 500 meters from the takeoff point for a drone of in between 2 and 15 kilograms. For a drone that weighs less than 2 kilograms the distance will be stipulated with the range of the radio station.
The maximum height, the same as the previous point, is limited, in the Spanish territory is of 120 meters.

The biggest limitation, without doubt, is the battery life. They usually last quite a short time but it is currently being researched and improved to be able to fly for a longer period of time.
Urban areas, high density population.
Proximity to airports.

Location.

The roman villa of *"La Llosa"*, which is the place of study of this work, is located in the neighbourhood of *La Llosa* in *Cambrils.* It is delimited with *Manuel Hidalgo* Street in the North, *Sant Jaume* Street in the East, on the West works as an intermediary with the ravine of *Mare de Déu del Camí, Josep Iglesias* street and, in the South with the Mediterranean sea and *Passeig Marítim de Ponent.* Located in the region of the *Baix Camp* in Tarragona province, in Catalonia.

Figure 1. Topographic map of Cambrils scale 1:25,000. From the ICGC, modified.

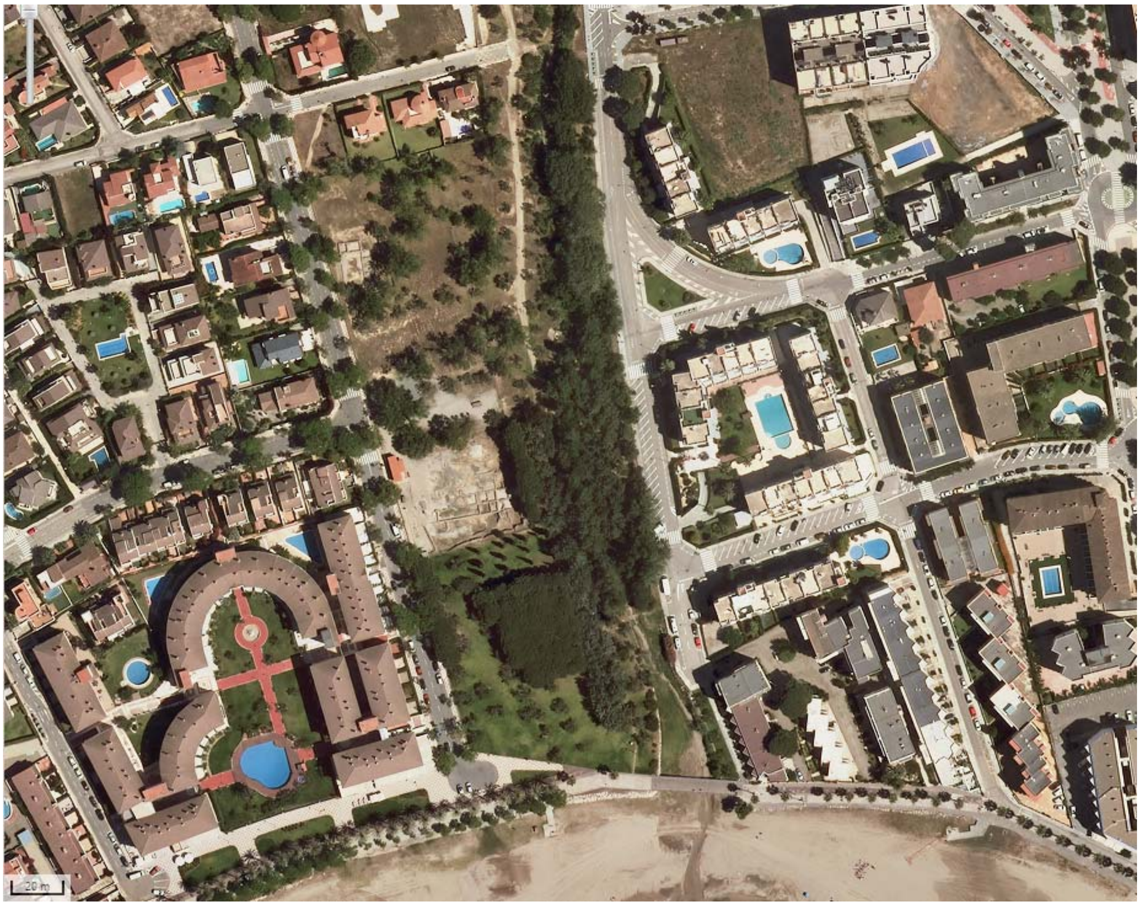


Figure 2. Orthophotography scale 1:5,000. From the ICGC, modified.

Roman villa of *La Llosa.*

The remnants of this finding constitute the Roman villa of *La Llosa.* A villa of the Roman times in the old *Tarraco* established between the 1st and 6th century AC. It is one of the most important findings of the municipality of Cambrils and the Tarragona province. Is based on a private house of a well being Roman family of around 900 square meters oriented towards the sea and with a land extension of 7,750 square meters nowadays, which is supposed to be of a wider set of land in the past, which supposedly had been deformed or had collapsed in posterior remodelations.

Because of his archeological and historical interest the finding has been catalogued as a Cultural Good of Local Interest. Apart from giving us a lot of information about the occupations of people in the Roman times in Tarraco, this type of building was a familiar house model essentially Italic. It was moved to the provinces along the territory that the empire occupied and symbolized a new evolution in the agricultural world. Is it because of this motive that in this villa, like in many others, they started to build structures that went beyond a simple agriculture exploitation, that can evoke the known *"urbe in rure".* A mix between urbanization and the rural environment, between the artificialism of the cities and the traditional lifestyle in the rural area. All this is mixed in the *La Llosa* vila: it has a part of *"domus"* and habitacle area along with a rustic *"pars"* and *"fructuaria"* in which they were self-sufficient and productive.

The origin of the villas and their development is related with the potential agricultural merchants in the Mediterranean sea (in this case), along with the close urban areas. Because of this, the placement of this villas (of course the one in *La Llosa* as well) was one of the most important elements, it should be close to cities and near fast travelling lanes as well as communication ones, but always taking into account the crops areas surrounding them.

We cannot forget the great merchant vision and commercial projection that was characteristic of the Roman Empire and that was imprinted in constructions such as the villas. One of the most affected provinces were the Hispanic ones, specially the Tarraco province with its exportation of wine and oil. In addition, our research villa, because of its location, had also exported fishing resources. In fact there were studies that proposed the presence of a salted fish fabric in *La Llosa,* although in the present they have discarded the idea (García, Puche 2000). *La Llosa, La Pineda, Altafulla, el Vilarenc* and *Darró* were the most known maritime villas in the *ager Tarraconensis.*

The villa in *La Llosa* it is also known for its oven of Augustinian era, in which ceramics were made, constituting a small artisan center. Regarding the livestock there are still very few studies in archaeology that can demonstrate the presence of animals in this site.

Architectonic description.

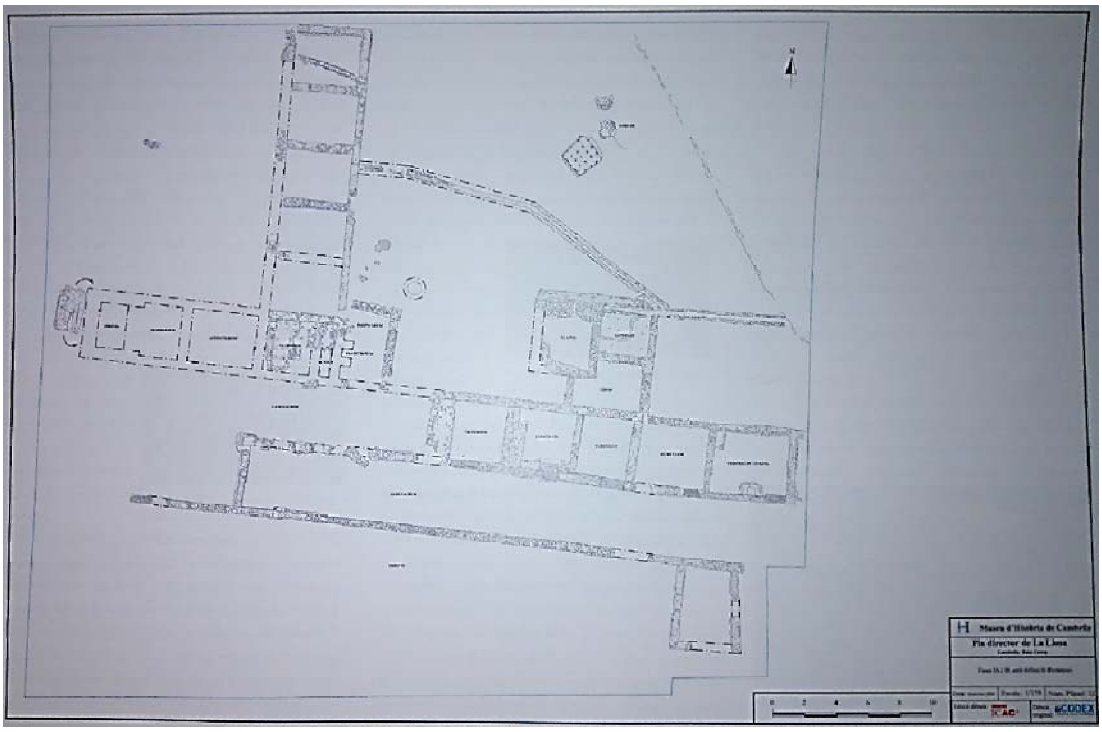


Figure 3. Base floor top view in its maximum splendor time. With the definition of the rooms.

The Roman villa in *La Llosa* rests over a quaternary platform with clays and sands formed by fluvial deposits generated by the ravine of the *Mare de Déu del Camí* and at a low altitude from the sea level. We're talking about a fertile terrain apt to all kind of harvesting, such as wine and oil. Elements that were part of the landscape of the area.

The remains of the constructions are considered very important because almost the entire floor has been conserved: The residence, the agricultural production structures, industrial and storage. For what it has been observed until now the construction has been framed in the Republican era, before the Imperial period, and has great historical and architectural value to be able to know the rural population of Tarraco before emperor August.

The definition of a villa is pre established, since its distributed in three parts:

Urban Pars. Living area of the owners, from were the villa was managed and the exploitation aspects were organized.
Rustic Pars. Living area of the slaves, in this area we can also find the kitchen, tools and stables.
Fructuary Pars. Area dedicated to the elaboration, storing and product making.

From these significative elements our villa shows the three parts with the following details:

Urban Pars. Made of a corridor (in this case a *Cryptoporticus)* that organizes the space and distributes the different rooms: A dining room (*triclinium),* the rooms (*cubicula*), and a big garden (*hortus*) in front of the sea. On the higher level, the bathrooms (*balnea*), the kitchen (*culina*), a latrina (*latrina),* and a pantry (*cella*).
Rustic Pars. Divided by a row of chambers and an oven. We know of the existence of other structures nearby that were possibly linked to storage and the product making.
Fructuary Pars. Fields cultivated with olives, vineyard and other crops. They are actually occupied by recent constructions.

Restoration of the roman villa in *La Llosa* of Cambrils.

The Roman villa in *La Llosa* was found in 1980. The urban changes by that time with the construction of summer houses near the beach along with campings for tourists became the inducers of the finding, the land movement in order to get the surface ready revealed the archaeological remains.

It wasn't until 1982, after the retrieving of the first objects from the area by experts, that the site reached the grade of importance that it deserved. Since this moment the excavations were made without a proper control over them. Only the archaeologist Jaume Massó identified some of the findings and put them into context.

In 1982 the area was included in a partial plan of Cambrils town hall in order to protect the remnants by prohibiting the urbanization and construction in the area.

From 1983 to 2008 a group of campaigns were made in order to broaden the finding of the villa, locating new findings and making a maintenance over the excavated area.

Figure 4. General top view of the structures, indicating their conservation state.

Process organization.

In the following paragraphs we will describe the steps that were followed in this final degree project.

After choosing the theme, the exact location of the work and the techniques we will use we will start the bibliographic study in order to locate, contextualize and describe the location of *La Llosa,* Making a small histographic, arqueologic, and arquitectonic introduction of the remnants in order to remark the importance they have for the city of Cambrils and its historic and cultural heritage. Apart from the documental and bibliographic research we will make a brief introduction to the world of photogrammetry, its uses, advantages and procedures.

After the making of the teoric frame, we will start to scheme the practical aspects, making a small study with the intention of choosing the processes to make in order to reconstruct the remnants. The results that we pretend to obtain with this practical part it has to be more precise and reliable as possible, for this reason we need to choose wisely the procedures.

The possible ways to make the surveys were the following: a photogrammetric survey using the conventional method (a photo report with camera in hand). A second method would be similar to the first but using a perch of 5 meters in an oblique position. The third idea would be to take the images through a drone and a GoPro camera that takes the instants. The latter option was to use the laser scanner to be more precise and faster the necessary points.

While considering all the options we came to the conclusion that by mixing all these procedures we would obtain a better result and, since we have available all the apparel and time we started with the field work.

We also found convenient to give coordinates to points in order to generate a polygonal in order to locate and put in its real location the survey. We started from two points with known coordinates from the *Institut Cartogràfic i Geològic de Catalunya (ICGC),* by stationing and orienting the station we developed the four points polygonal: A, B, C, and D.

In the end we will make all the previous procedures by using softwares like Agisoft PhotoScan, SCENE, CloudCompare and AutoCaD with its MDT extension. All of them were necessary in order to develop the project in their time. At this point we will also explain the methods used in each case. In the development of this work we will also explain the techniques and the way we used them in every procedure.

The total amount of field sessions was three, the first session developed was the creation of the polygonal, so that the project would continue and we could give it coordinates in Universal Transverse Mercator (UTM).

The second session was the creation of the cloud points with the help of the laser scanner, we made twenty two different captures in order to capture all the different angles, in this session we also made the takes with the drones after planning the flight sequence.

And finally the third session we made the surveying with conventional cameras to give a possible coverage to the drone.

Application in the field of heritage conservation.

By using the process of recording, measurement and interpretation of the different photographic representations we can manage to reach exact data of the three dimensional models, hereby the photogrammetry can be considered a very useful tool for studies and valuations of architectonic heritage.

Most part of the photogrammetric project is made in a technical office, but the beginning of the process is in taking photographs, which have to be of optimal quality in order to have good final results, to be able to generate a network to give dimension and orientation to the photogrammetric survey.

Thanks to the development and the improvements on the software, nowadays, without the need of professional cameras we can get quite satisfactory results. With an acceptable precision, even to apply it to professional jobs, both arquitectonic and surveys like the one we're doing. Which is the reason why the studies using this technique have increased in the past years.

The usual objective of a photogrammetric survey is to generate a three dimensional model of an object in order to study it, in any ambit, rebuild it, in the archaeological case, or decompose it in the architectonic one or even make ground studies in other fields of studies.

Said model will consist on the overlapping of two stereoscopic images (minimum) and, through an informatic software, the restitution program will follow a procedure and calculations that will give way to a three dimensions model.

Said process will digitize points of the object and once dimensioned and oriented it will show the object through the visualizer of the same program or through another one as long as it is saved in the correct format, depending on our needs we will use a software or another.

We need to remark that the precision that can be gained nowadays is linked necessarily to the access to the studied object and the scale of the photographs taken.

Photogrammetry is a technique that has been considerably used in this field of work and its spreading widely with the help of tools like the laser scanner, that by using different stationery it offers an alternative to the photogrammetry in field work, a more precise technique.

What we do is generate the cloud point with a Laser Scanner and we insert the color in the cloud through photogrammetry. The first tool has more precision to take points and the second step will be to take photographs. When joining the two gives a result of a more precise job.

Tools for the surveying.

Cameras

In this survey we’ve used two different cameras: Camera Nikon D90 and Nikon D5300.

The first one is a middle quality camera, one that anyone can have at home and can be used in photogrammetry, the second one a high resolution camera.

Nikon D90.

GENERAL	
Camera type	Reflex digital camera
CAPTURING THE IMAGE	
Effective Pixels (megapixels)	12,3 millions
Sensor measurement	23,6 mm x 15,8 mm
Area of the image (pixels)	4,288 x 2848
Pixel measurement	5,5
OPTIC	
Focal distance	35 mm - 450 mm
Zoom	Automatic
Aperture	f1,4 - f22

EXPOSURE CONTROL	
Shutter speed	Maximum: 1/4000 s
	Minimum: 30s
Exposure compensation	Grade: de - 5 a + 5 EV
	Increments: 1/3
Sensitivity	Expanded maximum: Lo-1 (equivalent ISO 100)
	Expanded minimum: Hi-1 (equivalent SO 6,400)

Table 1. Camera specifications Nikon D90.

Nikon D3500.

GENERAL	
Camera type	Reflex
CAPTURING THE IMAGE	
Effective pixels (megapixels)	24,2 millions
Sensor measurement	23,5 mm x 15,6 mm
Area of the image (pixels)	6000 x 4000
Pixel measurement	3,89
OPTIC	
Focal distance	50 mm - 450 mm
Zoom	Automatic
Aperture	f1,4 - f22
EXPOSURE CONTROL	
Shutter speed	Maximum: 1/4000 s
	Minimum: 30s
Exposure compensation	Grade: de - 5 a + 5 EV
	Increments: 1/3 o 1/2 EV
Sensitivity	Expanded maximum: 100
	Expanded minimum Expanded: 12,800

Table 2. Camera specifications Nikon D5300.

GoPro Hero 4 Black

GENERAL	
Camera type	Camera digital
CAPTURING THE IMAGE	
Effective pixels (megapixels)	12 millions
Area of the image (pixels)	4000 x 3000
Pixel measurement	5,5
OPTIC	
Focal distance	8,8mm a 24 mm (equivalent a 35 mm)
Zoom	Automatic
Aperture	f2,8 - f21
EXPOSURE CONTROL	
Mechanical shutter speed	Maximum: 1/2000 s
	Minimum: 8s
Electronically shutter speed	Maximum: 1/8000 s
	Minimum: 8s
Automatic sensibility	Expanded maximum: 100
	Expanded minimum: 3,200
Manual sensibility	Expanded minimum: 100
	Expanded minimum: 12,800

Table 3. Camera specifications GoPro Hero 4 Black.

Drone.

GENERAL	
Weight	1,388 kg
Diagonal dimension	350 mm
Maximum ascent speed	3 R
Minimum descent speed	20 mW
Maximum speed	905 nm
Maximum wind resistance	153,49 m
Maximum flight time	0,6 a 120 m
Operating temperatures	Maximum: 40 ºC
	Minimum 0 ºC
Satellite positioning system	GPS and GLONASS
GPS stationary flight accuracies GPS	Horizontal: + / - 0,5 m
	Vertical: + / - 1,5 m
Manual stationary flight accuracies	Horizontal: + / - 0,1 m
	Vertical: + / - 1,5 m

Table 4. Specifications Drone Phantom III.

Total Station Total. Topcon ES 105

Telescope	
Length	171 mm
Aperture	45 mm
Length magnification	30 X
Image	Direct
Visual	1 º 30' (26 m / 1,000 m)
Minimum focusing distance	1,3 m
Angle measure	
Minimum Resolution / Precision	1'' / 5''
Compensation	Double axis
Precision	5''
Distance measure	
Laser output	Mode Sheet Class 1
EDM Prism Range	4000
EDM Prism Precision	2 mm +2 ppm
Prove without prism	500
Precision without Prism	3mm + 2 ppm (0,3 - 200 m)
Measuring time	Fine: 0,9 seg. - Quick: 0,7 seg. - Tracing seg.

Table 5. Total station specifications. Topcon ES 105.

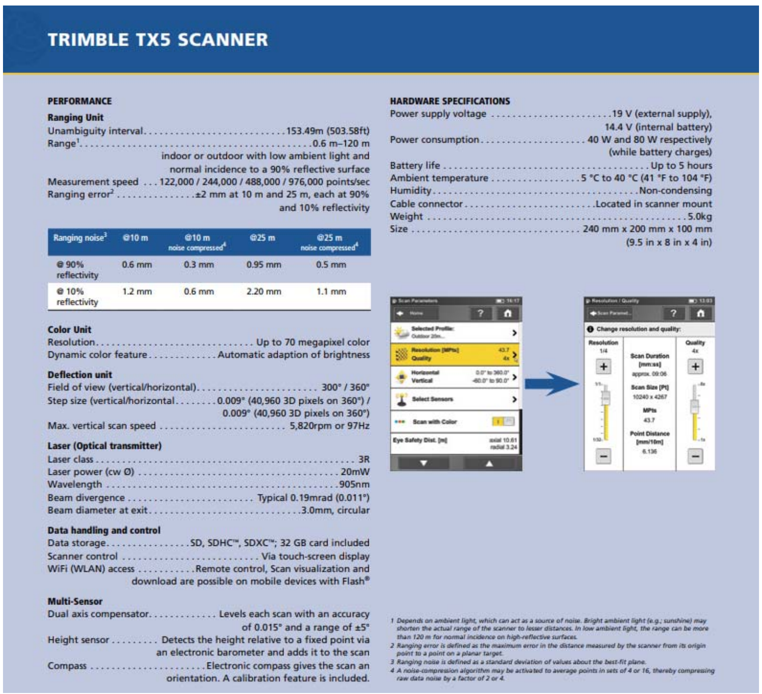
GPS. HiPer SR

GNSS tracing	
Number of channels	226 able to follow 112 satellites
Tracking signals	L1, L2, L2C, GPS, GLONASS, SBAS, QZSS
Antenna type	Integrated antenna
Precision	
Static / Fast Static	Horizontal: 3,0 mm + 0,4 ppm
	Vertical: 5,0 mm + 0,6 ppm
Static Position	Horizontal: 3,0 mm + 0,1 ppm
	Vertical: 3,5 mm + 0,4 ppm
RTK (L1 + L2)	Horizontal: 10 mm + 0,8 ppm
	Vertical: 15 mm + 1,0 ppm

Square 6. GPS HiPer SR specifications.

Laser Scanner Trimble TX5.

The first plan that we had, to do the surveying, was to use the photographs in order to make the reconstruction of the Roman remnants in *La Llosa* of Cambrils but, due to the degree of details in the construction we finally decided to use the Laser Scanner to take the points in black and white and then we will add the color with the photographs of the cameras.



TRIMBLE TX5 SCANNER

PERFORMANCE

Ranging Unit

Unambiguity interval 153.49m (503.58ft)
Range[1] .... 0.6 m–120 m indoor or outdoor with low ambient light and normal incidence to a 90% reflective surface
Measurement speed ... 122,000 / 244,000 / 488,000 / 976,000 points/sec
Ranging error[2] .... ±2 mm at 10 m and 25 m, each at 90% and 10% reflectivity

Ranging noise[3]	@10 m	@10 m noise compressed[4]	@25 m	@25 m noise compressed[4]
@ 90% reflectivity	0.6 mm	0.3 mm	0.95 mm	0.5 mm
@ 10% reflectivity	1.2 mm	0.6 mm	2.20 mm	1.1 mm

Color Unit

Resolution .... Up to 70 megapixel color
Dynamic color feature .... Automatic adaption of brightness

Deflection unit

Field of view (vertical/horizontal) .... 300° / 360°
Step size (vertical/horizontal .... 0.009° (40,960 3D pixels on 360°) / 0.009° (40,960 3D pixels on 360°)
Max. vertical scan speed .... 5,820rpm or 97Hz

Laser (Optical transmitter)

Laser class 3R
Laser power (cw Ø) 20mW
Wavelength 905nm
Beam divergence .... Typical 0.19mrad (0.011°)
Beam diameter at exit .... 3.0mm, circular

Data handling and control

Data storage .... SD, SDHC™, SDXC™; 32 GB card included
Scanner control .... Via touch-screen display
WiFi (WLAN) access .... Remote control, Scan visualization and download are possible on mobile devices with Flash®

Multi-Sensor

Dual axis compensator .... Levels each scan with an accuracy of 0.015° and a range of ±5°
Height sensor .... Detects the height relative to a fixed point via an electronic barometer and adds it to the scan
Compass .... Electronic compass gives the scan an orientation. A calibration feature is included.

HARDWARE SPECIFICATIONS

Power supply voltage .... 19 V (external supply), 14.4 V (internal battery)
Power consumption .... 40 W and 80 W respectively (while battery charges)
Battery life .... Up to 5 hours
Ambient temperature .... 5 °C to 40 °C (41 °F to 104 °F)
Humidity .... Non-condensing
Cable connector .... Located in scanner mount
Weight 5.0kg
Size .... 240 mm x 200 mm x 100 mm (9.5 in x 8 in x 4 in)

1 Depends on ambient light, which can act as a source of noise. Bright ambient light (e.g.; sunshine) may shorten the actual range of the scanner to lesser distances. In low ambient light, the range can be more than 120 m for normal incidence on high-reflective surfaces.
2 Ranging error is defined as the maximum error in the distance measured by the scanner from its origin point to a point on a planar target.
3 Ranging noise is defined as a standard deviation of values about the best-fit plane.
4 A noise-compression algorithm may be activated to average points in sets of 4 or 16, thereby compressing raw data noise by a factor of 2 or 4.

Table 7. Laser Scanner specifications, Trimble TX5

Hardware

To develop this project we've used our personal computer. The developed tasks were the photograph management, the total station point management (along with the GPS data), information research and the redaction of them.

The following description is the definition of its components:

Operating System: Windows 10 Pro

Processor: Intel® Core(TM) i5-4440 CPU 3.10 GHz.

RAM Memory: 24 GB

System Type: Operating System of 64 bits

Hard drive: SSD of 110 GB and HHD 1 TB

Graphic Card: NVIDIA GeForce GT630

Software.

In order to manage the images, make the graphical surveying and its representation in three dimensions (3D), we've used the following programs.

To generate the model in three dimensions from two dimensional photos we used Agisoft Photoscan Professional Version 1.4.3.

Agisoft is a company founded in 2006 owner of a software (PhotoScan) that processes digital images, by following a combination of digital photogrammetry techniques and a computer visualizer generates the reconstruction in three dimensions (3D) of the surroundings.

To join the different cloud points gained thanks to the Laser Scanner we used the software SCENE of FARO.

SCENE of FARO is a company founded in 1981 and is able to process cloud points, its register and the output of the cloud points generated by the Laser Scanner, it is a software easy to handle since the processes are automated, with the exception of the archive input.

To merge the cloud points from both the laser scanner and the photographs we used the CloudCompare software.

CloudCompare is a tool designed by the engineer Daniel Girardeau-Montaut, it is a software to compare and make studies towards the cloud points. In between the objectives or functions of this system there's the creation of nets and surfaces, point classification, register of different cloud points, etc.

Other Elements

In the different points of the polygonal, that was generated with the total station, and were homogenicaly located around our study object, we've placed a group of targets that we will use in order to georeference the model that was created.

We've generated two different types of targets.

The first target is a square of 18 cm x 18 cm over a din A4 sheet, inside the square there are four more squares of 8.5 cm x 8.5 cm in black and white diagonally opposed in order to create the target. This target of great dimensions will be located in such a way that it will be captured in the images taken by the drone.

The second target, built the same way as the first but with reduced dimensions (the square is of 8 cm x 8 cm and the small squares of 3.8 cm x 3.8 cm), will be used in the ground images taken from both the standing up camera or by using the tripod.

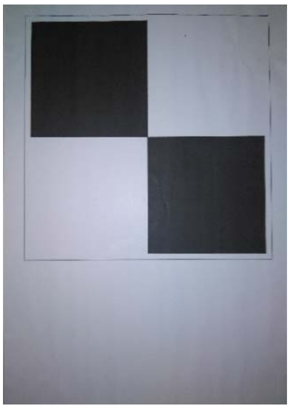


Figure 5. Aerial target.

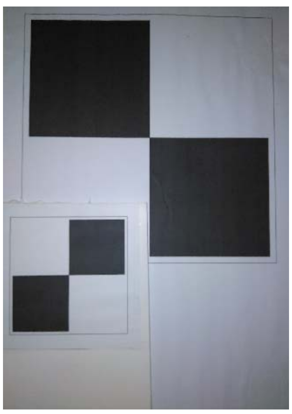


Figure 6. Ground target.

Data collection.

The data collection starts with the study of the surroundings, the remnants of *La Llosa* in Cambrils. As said before, it is located on the coast of the Mediterranean Sea, 200m away from the coast line, separated by a green area with olive trees and pine trees. Once we knew how it was distributed in space we looked for a way to locate the coordinates in the surveying area, we checked the *Institut Cartogràfic de Catalunya (ICGC)* to see if there was any vertex near the area, we found two of them, 262141019 and 262141020. When going to check if the two vertexes were visible from one another, around four hundred and fifty meters, we realised that the point 262141020 was covered by a wooden bridge that was built above.

You could see the reviews in the annex.

In the end we chose to put two bases measured with GPS, Global Positioning System, with the Fast Static Relative method, a method with which you make observations every five or ten minutes per station, we acquire precisions that go around the 5 mm and 10 mm (+1ppm).

We chose this method instead of the Standard Static Relative Method because the distance between the two bases observed was less than twenty kilometers, and the technique is faster, easier and more simple along with being more efficient for this kind of distances.

Once we've obtained the two bases, generated purposely for this work, by using the GPS, they were the origin to start to work with the total station and establish the polygonal that would give way to all the surveying giving the UTM coordinates and dimension to the three dimensional model.

Due to a lack of GPS signal in the area because of the buildings around the area and the vegetation we could not make the polygonal by using GPS.

Once we station in one of the new bases with the total station we will use the other base we could obtain with GPS to target the system.

Once the system is targeted we will mark our first base of the polygonal, out of a total of five that will be scattered in a way that they surround the studied area, two of them will be located on the sidewalk on the street on the left of our location, two more in the green area, and the fifth inside the area of study, on its green area in the lower part of the Roman remains.

The positioning of all the bases was made so that you can see all of them from each of them at the same time (full view).

Because of how they were placed we could make readings in between all the bases which made us have a network that reduced the errors that could have been obtained while taking point data.

From base "A" we made observations to the other points chosen to build the polygonal: "B", "C", "D", and "E".

This procedure has been made in every base.

The second block of the data collection comes from the photogrammetric survey. As mentioned previously, the data will come from three different types of photogrammetric surveys, with three different camera models.

The first survey was done with the camera Nikon D90. Said survey was made from the limit of the perimeter and in a perpendicular way from it when capturing the inside of the remains.

We made two sessions. The first one from the perimeter and the second one over an imaginary perimeter located in the middle of the first.

Photographs were taken every 2 or 3 meters.

Figure 7. Photographies every 2 – 3 m Nikon N90.

The second procedure has been made with the camera NikonD5300, this survey was made by placing the camera over a periscopic pull and we proceeded to make the survey through a mobile app connected to the camera through the bluetooth system. The method used to take the photographs was to place ourselves in perpendicular towards the Roman remains of the building, the camera in an oblique position with a displacement between each photograph of 2 or 3 meters, just like the last photo taking.

Figure 8. Photographies every 2 – 3 m Nikon D5300.

At last, with the camera GoPro Hero 4 Black installed in a drone we made the last photography coverage.

In order to be able to take the photographs in a proper way we designed a flight plan in order to obtain the whole structure extension of the object we want to represent. The photograph capturing had to cover all the possible angles from the different viewpoints.

Generate a flight plan is a fundamental step in order to obtain the stereoscopic coverage that we need. We have to take into account different external factors that may take part in our plan such as the proximity to trees or buildings, the weather and climate as there is the possibility of strong winds that may cause the images to turn out blurry, out of focus or without the necessary coverage to manage them in the lab, like the one that takes into account the lightning of the object.

We also need to sketch out the path of the survey over the remnants, the images will be taken every three seconds, because of the speed the drone will be maintaining we will first take the photos in a transversal direction followed by the longitudinal taking in order to catch all the possible angles and points of the arquitectonic element.

The following figures show the two flight plans.

Figure 5. South – East –- North – West Flight plan.

Figure 6. South – West -– North – East Flight plan.

At the time of the photogrammetric coverage we had to take into account the speed in which we would do the flight since we had to take the pictures for the survey, we needed to take into account the time between frames, the GSD value (Ground Sample Distance), that is equal to the value of the distance that represents in the ground every pixel. For example, a GSD of five centimeters means that every pixel is the same as five centimeters in the ground, a GSD value less than five will be considered as a good resolution and consequently any other value greater than five would be considered as bad resolution.

In resume, to determine the coverage we need to know the following aspects:

The total covered distance, “D” in meters.

The overlapped distance between two images, “od” in meters.

The distance between two camera positions, “x” in meters.

Speed in flight, “v” in meters per second.

The time of photo taking, “t” in seconds.

The desired overlap, in percentage.

Formulas:

od = Overlap distance

$$x = D - od$$

$$t = \frac{x}{v}$$

The width of the sensor is located in parallel to the flight direction, because of this:

$$D = Dw = \frac{IMW\ GSD}{100}$$

Dw is the traveled distance in the direction of the image's width.

IMW is the width of the image's pixel.

GSD is the desired GSD.

For that reason,

$$x = Dw = Overlap\ in\ Dw$$

$$x = Dw * (1 - Overlap)$$

$$x = \frac{IMG\ GSD}{1} * \frac{1 - Overlap}{v}$$

Treatment and data management.

Agisoft PhotoScan.

Once we've obtained the necessary images in order to make the graphic survey we insert all the data in the program.

This software can work in different formats like JPEG, TIFF, PNG and others. In our work we'll use the JPEG format since we've saved all the photographs in this format.

The software's structure is divided into three different parts: the workspace, where we have in detail all the processes that we do through the whole project; the model space, where we can see the compiled images and the survey according to the procedures; and the last one is the image space where we can see all the photographs taken into account for the project with a miniature for each.

In order to start to work with the photographs that were previously taken in the field we will generate a single workspace, this way we will be able to work jointly with other imaging methods while uploading the different photographs in order to proceed with different tasks.

We need to take into account that while uploading the pictures the processes that will be done a posteriori will be slowed down but, if we do not upload enough pictures we would likely have an issue with the coverage of the project.

In our case we have no other option than to add a lot of images, our element of study has the peculiarity of having an uneven surface as it has been mentioned along the project. They're the remains of a building of the Roman times, made of stone. such constructions generate a lot of shadows due to their unevenness so we need to upload more images than usual.

Images.

The images were taken with the highest resolution cameras allowed, 12 megapixels, 12.3 mp and 24.2 respectively, this way we could have more pixels and, as a consequence, more points for the model's reconstruction. The images' measurements are of 4,000 x 3,000 pixels, 4,288 x 2,848 pixels, and 6000 x 4000 px. The first digit corresponds to the width and the second to the height.

Aerotriangulation

In order to get an optimal result in the triangulation and to get a three dimensional position of each point that generates the model in three dimensions it is of vital importance to know the tools that we are using, both the internal (intrinsic), and external (extrinsic).

Intrinsic parameters are those that define the internal and optic geometry of a camera. They determine how the camera projects the points of the 3D world into the 2D image. They are constants and, because of that, they do not change the camera's characteristics or the relative positions between the optics and the image sensor. These are detailed in the following figure.

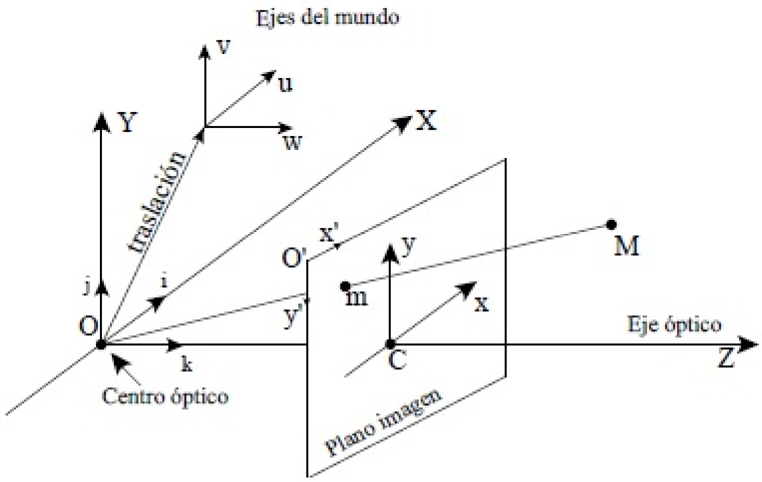


Figure 11. Intrinsic parameters.

The principal point "C" is the intersection point between the general image and the optical axis, the straight line perpendicular to the general image and goes through the center of the camera "O". The coordinates of this point are given in pixels and are represented towards the solidary system in the general frame of the image, "O", "x'", and "y'".

Focal distance, the existing distance between the camera, "O" and the main point. The coordinates of this point are given in horizontal and vertical pixels.

Distortion, established as a polynomial function that allows to determine the separation between the real point and its theoretical position.

Extrinsic parameters, those who define the camera's position at every moment while taking every photograph. This information can be obtained by using a GPS, or the own machine, or that the aircraft we are using has an inertial measuring system that allows us to know the location and orientation of each photograph.

T translation vector, it determines the location of the camera's optical center "O" towards the axis on the real world.

R rotation matrix, relates the rotation of the camera's position, "O", "X", "Y", and "Z" towards the axis of the real world.

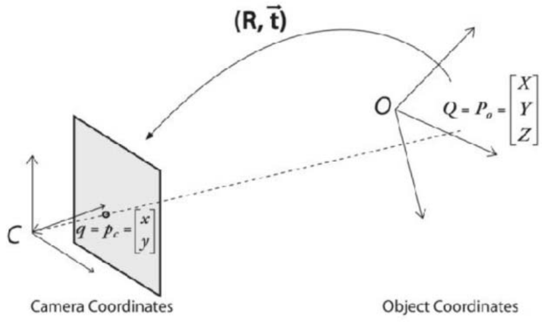


Figure 12. Extrinsic parameters.

In order for the process becomes satisfactory we need to calibrate the different cameras that we need to use, or either bring them to a specialized laboratory or using a check board, a crosslinked plaque of great stability with perfectly defined reticular points. The second step consists in taking pictures of the plaque and checking the coordinates of the plaque and the results after measuring the image so that we can establish the internal calibration parameters of the camera.

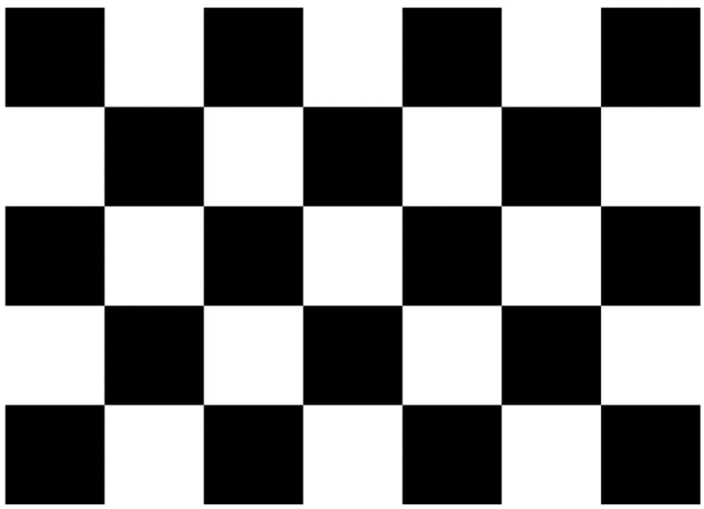


Figure 13. Comprovation plaque.

The following step is to orient the uploaded images, this process searches for similar points between images and joins them in order to create a sparse point cloud. This arrangement allows us to identify a group of matching pixels with the overlap of the different photographs in order to be able to show us from which position were the photographs taken.

The correspondence between points of interest is gained by indagating of the closest point in space. To associate points of interest of different images we need a defined vector from magnitude and orientation values.

Block adjustment

The method to make block adjustments is done through the use of beams produced by the different individual photograms, where the convergent configurations produced by a multiple position of the camera. This is one of the parts where the topographic work, because of their nature, with the axis of the camera, have to be nearly parallel in order to obtain better results. Nonetheless this system generates a great deal of equations and we need a great power of calculus, this is where the hardware we use gets to work.

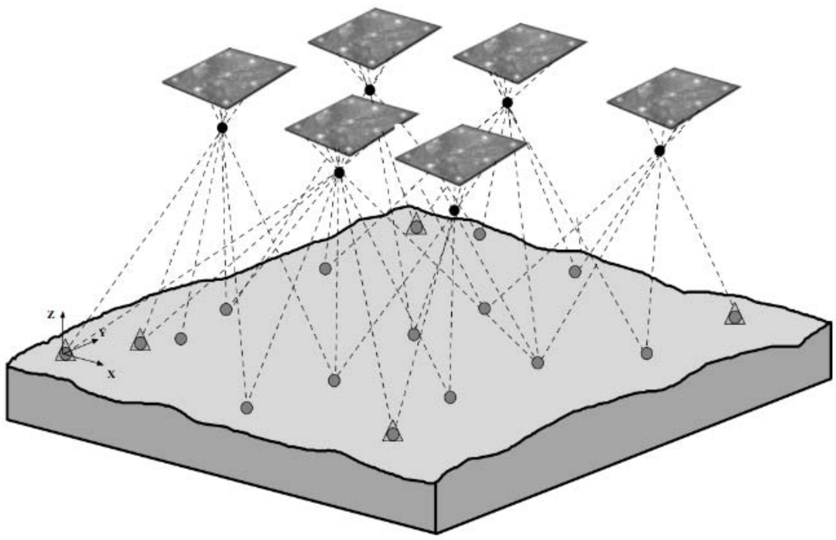


Figure 14. Basis of beams block adjustment.

The basis of this adjustment relies on the beam lights move in three translations and three rotations, cutting one's trough the others with the major and minor control points.

The initial data necessary to make the adjustment are:

The intern photogram orientation parameters (c, xo, yo, xF, yF).

The external photogram orientation parameters (Xo, Yo, Zo, ω, φ, κ).

The image coordinates of the minor and major control points (x', y').
The ground coordinates of the support points (X, Y, Z) along with the approximate coordinates of the points that appear in more than a single photogram and we wish to calculate their compensated coordinates in both the adjustment and the block compensation and at the same time.

Dense point cloud

After generating the disperse point cloud and block adjusting it is possible to build a dense cloud point from the cloud of points obtained in the first step that will reflect the geometry of the object with more detail. In this step the program calculates the depth of the images by combining them in a single point. The information in these points is composed by coordinates X, Y and Z in a cartographic system along with the color value saved in RGB, Red Green Blue.

We obtained a total amount of 83.8 million of points, thus generating our dense cloud of points.

Figure 15. Dense point cloud.

Deleting wrong points

Once the dense cloud of points is generated we are able to delete those points that do not match with reality or they are in a region that it is not of our interest, like the points from the surroundings of the building.

Said action will be made using the same software that has a tool to edit points.

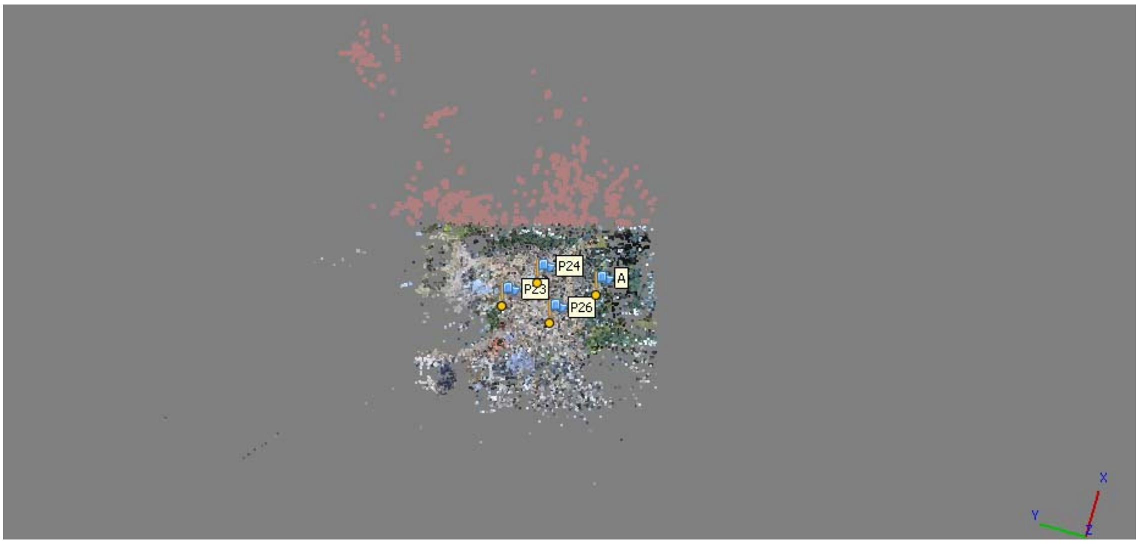


Figure 16. Deleting wrong points.

Mesh creation

We will also generate a triangle mesh from the dense cloud point once it has been cleaned. It will constitute the three dimensional model through the use of the Triangular Irregular Network (TIN) process. We need to configure it well in order to obtain the result we hope for.

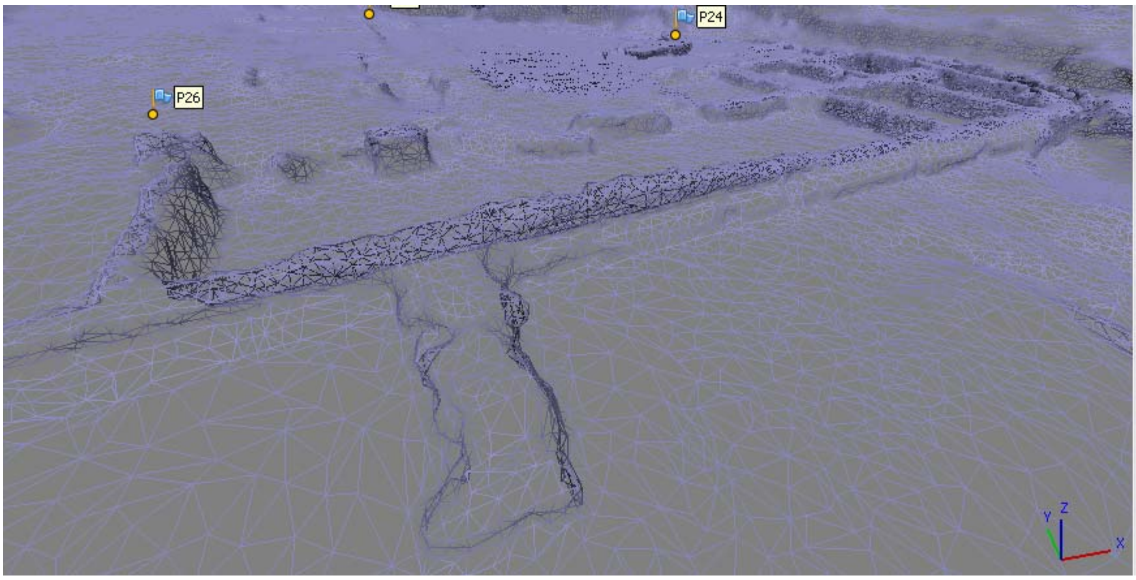


Figure 17. Basis of beams block adjustment.

Texturized

Finally, the points in three dimensions are reprojected to the original images in order to achieve, this way, the corresponding color by doing an average of the different RGB values of the different images where the same point appears. These pixels with colorimetric information will generate a JPG image as shown below.

Figure 18. Texturitzed.

As the final annotation, the texturized three dimensional model, wil be generated, and it will be able to be exported in different formats (PLY, XYZ, PNT) to be able to work with it in other softwares.

SCENE

We generated a three dimensional model executed in all its totality with the FARO SCENE software. The laser scanner modeling takes the data through the phase difference, the machinery sends a group of waves with different longitude and makes a comparison with the rest of the sent waves and received again by the sensor of the same system. This way it determines the distance in which the points are found, by comparing the wave phase both sent and received.

The procedure to make a survey with a laser scanner is a simple technique and consists of different tasks.

Once they are finished we can edit and export the scan of the project to diverse types of formats that the same software allows.

The beginning of this process starts with the data collection. We’ve done a total of twenty two measurements to capture the points.

The next step is to transfer the data by using a memory stick in the USB port, the software sends the data to a folder that will allow to upload the data to a computer in order to work with them.

We will continue with the data processing which is an automatic process, what does the program is to look for similarities of points between different scans to look for concordances in order to adjust them at the same time that it warns us of which scans do not coincide and cannot be joined.

In order to help with the processing, we strategically distributed six spheres around the perimeter of the survey. This way the software is able to find similarities through different scans.

Afterwards we make the registering of the scans, to look for correspondences that can be found between cloud points that were made with the apparel.

As we previously said, the system looks for both the spheres and the targets that were also distributed around the perimeter.

Finally, after finishing to register the scans and once we’ve checked that the program was able to do the process the right way, without finding errors and has been able to find a correspondence between scans the system will generate the cloud points, a cloud of points made by joining the twenty two scans completely.

What we obtain by doing these processes is to obtain a survey that has refilled all the empty spots that a simple scan could leave empty since the same object can shade parts of itself. So with this we can get the maximum information of the object we are studying.

CloudCompare.

At the beginning we had planned to use this software to make the cohesion between the twenty two scans but due to the various difficulties we had while trying to work with such a big quantity of data it was impossible to do it on a conventional computer. for this reason we used a different software as we previously mentioned.

Nonetheless, this software has been used to give color to the cloud of points.

In order for the cloud point to be more manageable and to obtain a good result, we decided to make it in black and white and, later on, add the color to it.

The color for the points was taken from the cloud generated by the Agisoft PhotoScan software and the group of images that were taken from the different cameras.

Results.

Once we've processed all the data (photographs, point clouds, coordinates, etc.), and we merged them all, we obtained a cloud of points that are geographically georeferenced with the characteristic of color that we would not have been able to have if we only had focused on capturing points. Along with a mesh geometrically three dimensional that gave texture to the final result by taking external information from the images.

Thanks to this georeferencing, by taking a group of points from both the polygonal and other points of interest located around the survey, we were able to locate the survey on the map very precisely.

From these results we can take two different types of data. The geometric data, which is the data that we used to locate our survey of the Roman remains of *La Llosa,* along with any other point engulfed in the survey, that allows to know the absolute coordinates and distances between them; and the graphic data, the data that we observe, in this case the wall we modeled of the Roman building.

Conclusions.

The main objective of this project was the photogrammetric reconstruction of the Roman remains of *La Llosa* in Cambrils. We finished the project with satisfactory results, but they are not the ones we expected at first.

Mainly because of the lack of processing capability of my computer since all the imaging process (even if we discarded some photographs), the laser scanner scans (with more than 23 Gb in data), along with the correlation of points, the adjustment of the polygonal with the total station, and the GPS registering. All of this was too much for a conventional computer, not to forget we also had to add color to the cloud point with Agisoft.

But we must not forget that thanks to these techniques we are able to preserve part of our local interest heritage (in a digital way), and that it provides a small piece to the whole process to preserve these places with a historical value in case they get damaged in the future (be it because of the climate or because of human factors).

Another part of the project was to get to know the historical and arquitectonic aspects of the location. That, with a very exhaustive study through the Museum of History in Cambrils, and some documents found in books and publications, has allowed us to understand and explain how life was in those times.

I consider these remains as something more than an arquitectonic instrument, rather, I would like to think that it is also a place of knowledge and thought, which is why we need to try to preserve it as much as we can.

We also made a small introduction to all the technical aspects we need to take into account while doing a photogrammetric survey along with a small introduction to the world of photogrammetry.

We showed software as useful tools to obtain metric data (with good quality), along with object representations in three dimensions. They allow us to save up time at the time of drawing the objects, to have better quality at the time of representing it and, by the help of the drone, to access places of great difficulty. Allowing us to see a wide range of applications for these methods, and that are not only limited to the topographic world.

By the end of this project I came to the conclusion that this project could still be widened in the following ways:

- The reconstruction of the Roman villa of *La Llosa* from the study of the remains that are left in the present.
- Generate a catalogue with the monuments around the area along with their own survey.

Building a model having as the base the survey we made, this way keeping the remains “original”.

Use the survey as a pedagogical tool.

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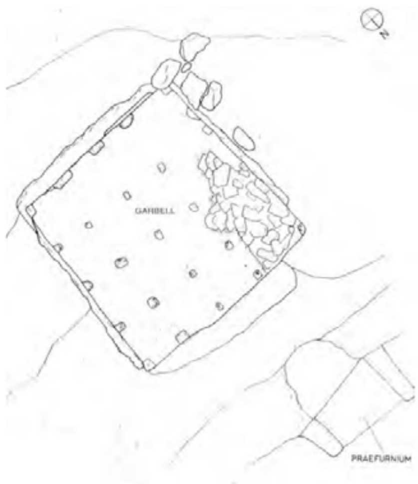
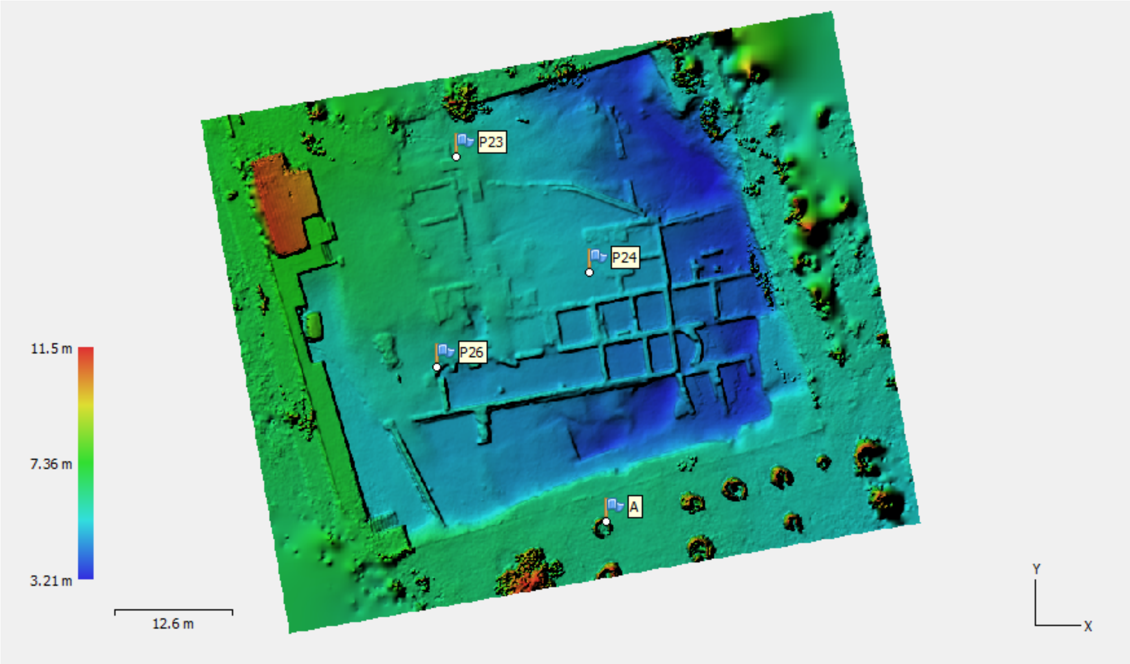
And at last, but not least, to the two watch drills, because despite the fact that they usually go too fast they've listened to me and had given me my space so that I could achieve what I wanted and be able to finish this project with a huge satisfaction.

Annexes



Forn de la vil·la de La Llosa a Cambrils (Garcia *et alii*, 2001, 124.125)

Planta de la vil·la de La Llosa a Cambrils (García *et alii, 2001).*



DEM

ORTOMOSAIC

REVIEWS

POINT A

Photogrammetric reconstruction of the Roman remnants of *Llosa de Cambrils*.

General information

Province: Tarragona

Region: Baix Camp

Town: Cambrils

Description: Stainless steel nail to which a target is placed so that the point can be identified.

Reference System ETRS89

Projection: UTM Zone 31 hemi N

X Projected: 336201.499 m

Y Projected: 4547874.425 m

Longitude: 1º 3’ 1.760’’

Latitude: 41º 3’ 56.293’’

Ortometrich height (H): 6.221 m

Map of the area

Detail

POINT B

Photogrammetric reconstruction of the Roman remnants of *Llosa de Cambrils*.

General information

Province: Tarragona

Region: Baix Camp

Town: Cambrils

Description: Stainless steel nail to which a target is placed so that the point can be identified.

Reference System ETRS89

Projection: UTM Zone 31 hemi N

X Projected: 336210.302 m

Y Projected: 4547981.933 m

Longitude: 1º 3’ 2.034’’

Latitude: 41º 3’ 59.783’’

Ortometrich height (H): 7.303 m

Map of the area

POINT C

Photogrammetric reconstruction of the Roman remnants of *Llosa de Cambrils*.

General information

Province: Tarragona

Region: Baix Camp

Town: Cambrils

Description: Stainless steel nail to which a target is placed so that the point can be identified.

Reference System ETRS89

Projection: UTM Zone 31 hemi N

X Projected: 336169.747 m

Y Projected: 4547883.648 m

Longitude: 1º 3' 0.391''

Latitude: 41º 3' 56.568''

Ortometrich height (H): 6.823 m

Map of the area

Detail

POINT D

Photogrammetric reconstruction of the Roman remnants of *Llosa de Cambrils*.

General information

Province: Tarragona

Region: Baix Camp

Town: Cambrils

Description: Stainless steel nail to which a target is placed so that the point can be identified.

Reference System ETRS89

Projection: UTM Zone 31 hemi N

X Projected: 336152.324 m

Y Projected: 4547944.086 m

Longitude: 1º 2’ 59.587’’

Latitude: 41º 3’ 58.515’’

Ortometrich height (H): 7.702 m

Map of the area

POINT P1

Photogrammetric reconstruction of the Roman remnants of *Llosa de Cambrils*.

General information

Province: Tarragona

Region: Baix Camp

Town: Cambrils

Description: Stainless steel nail to which a target is placed so that the point can be identified.

Reference System ETRS89

Projection: UTM Zone 31 hemi N

X Projected: 336185.525 m

Y Projected: 4547913.003 m

Longitude: 1º 3’ 1.039’’

Latitude: 41º 3’ 57.531’’

Ortometrich height (H): 6.195 m

Map of the area

Detail

POINT P2

Photogrammetric reconstruction of the Roman remnants of *Llosa de Cambrils*.

General information

Province: Tarragona

Region: Baix Camp

Town: Cambrils

Description: Stainless steel nail to which a target is placed so that the point can be identified.

Reference System ETRS89

Projection: UTM Zone 31 hemi N

X Projected: 336189.880 m

Y Projected: 4547901.442 m

Longitude: 1º 3’ 1.23’’

Latitude: 41º 3’ 57.160’’

Ortometrich height (H): 5.748 m

Map of the area

Detail

POINT P3

Photogrammetric reconstruction of the Roman remnants of *Llosa de Cambrils*.

General information

Province: Tarragona

Region: Baix Camp

Town: Cambrils

Description: Stainless steel nail to which a target is placed so that the point can be identified.

Reference System ETRS89

Projection: UTM Zone 31 hemi N

X Projected: 336199.672 m

Y Projected: 4547900.739 m

Longitude: 1º 3’ 1.656’’

Latitude: 41º 3’ 57.144’’

Ortometrich height (H): 6.037 m

Map of the area

Detail

POINT P4

Photogrammetric reconstruction of the Roman remnants of *Llosa de Cambrils*.

General information

Province: Tarragona

Region: Baix Camp

Town: Cambrils

Description: Stainless steel nail to which a target is placed so that the point can be identified.

Reference System ETRS89

Projection: UTM Zone 31 hemi N

X Projected: 336183.363 m

Y Projected: 4547890.747 m

Longitude: 1º 3’ 0.967’’

Latitude: 41º 3’ 56.808’’

Ortometrich height (H): 6.438 m

Map of the area

Detail

FITXA DE SENYAL GEODÈSIC

ICGC Institut Cartogràfic i Geològic de Catalunya

Informació general

Codi ICC:	262141019
Província:	Tarragona
Comarca:	Baix Camp
Municipi:	Cambrils
Full MTN50 (SQ/CCFF):	0472 / 33-18
Full MTN5 (CCFF):	262-141
Data de construcció:	01/10/2004
Data d'última revisió:	07/04/2015
Xarxa:	XU

Descripció:

Clau d'acer inoxidable amb la cabota formada per un tronc de piràmide de 4 cm de diàmetre superior i 3 cm de diàmetre inferior, situat sobre l'últim esglaó d'accés a la platja.

Coordenades

Sistema de referència: ETRS89/00

Projecció:	UTM Fus 31	Hemisferi N	
X Projectada (X):	335854.710 m	**σ:**	0.030 m
Y Projectada (Y):	4547625.600 m	**σ:**	0.030 m
Factor d'escala (K):	0.99993162		
Convergència quadrícula (ω):	-1º 17' 0.85919"		
Longitud (λ):	1º 2' 47.14825" E	**σ:**	0.00130 "
Latitud (ϕ):	41º 3' 47.97690" N	**σ:**	0.00097 "
Cota ortomètrica (H):	2.276 m	**σ:**	0.070 m
Model de geoide:	EGM08D595	**N:**	49.008 m
Cota el·lipsoïdal (h):	51.284 m	**σ:**	0.050 m
Referència de les cotes:	CSG		
Altura del pilar geodèsic:	0.000 m		

Té coordenades en ED50 (icc20060): Sí

ftp://geofons.icc.cat/fitxes/XU/ED50/262141019.pdf

Fotografia

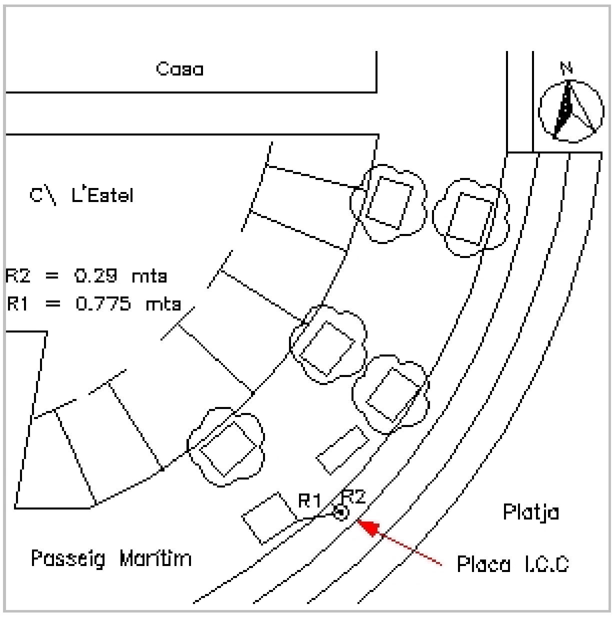
Versió de la fitxa: 20180.180717

Estat de conservació del vèrtex

Bon estat (sembla no haver sofert canvis des de la seva construcció).

Mapa de la zona

Accés / Croquis de la zona



Ubicació del vèrtex

Des de l'urbanització la Llosa, s'ha d'anar en direcció l'escola d'hosteleria. Al costat d'aquesta ens queda un carrer sense sortida (C/ l'Estel), fins arribar al Passeig Marítim.

ICGC Institut Cartogràfic i Geològic de Catalunya

FITXA DE SENYAL GEODÈSIC

Informació general

Codi ICC:	262141020
Província:	Tarragona
Comarca:	Baix Camp
Municipi:	Cambrils
Full MTN50 (SQ/CCFF):	0472 / 33-18
Full MTN5 (CCFF):	262-141
Data de construcció:	01/10/2004
Data d'última revisió:	07/04/2015
Xarxa:	XU

Descripció:

Clau d'acer inoxidable amb la cabota formada per un tronc de piràmide de 4 cm de diàmetre superior i 3 cm de diàmetre inferior, situat damunt la vorera del pont peatonal.

Coordenades

Sistema de referència: **ETRS89/00**

Projecció:	UTM Fus 31	Hemisferi N	
X Projectada (X):	336275.820 m	**σ:**	0.030 m
Y Projectada (Y):	4547778.550 m	**σ:**	0.030 m
Factor d'escala (K):	0.99992992		
Convergència quadrícula (ω):	-1º 16' 49.23696''		
Longitud (λ):	1º 3' 5.03446'' E	**σ:**	0.00130 ''
Latitud (ϕ):	41º 3' 53.23952'' N	**σ:**	0.00097 ''
Cota ortomètrica (H):	4.106 m	**σ:**	0.070 m
Model de geoide:	EGM08D595	**N:**	49.006 m
Cota el·lipsoïdal (h):	53.112 m	**σ:**	0.050 m
Referència de les cotes:	CSG		
Altura del pilar geodèsic:	0.000 m		

Té coordenades en ED50 (icc20060): Sí

ftp://geofons.icc.cat/fitxes/XU/ED50/262141020.pdf

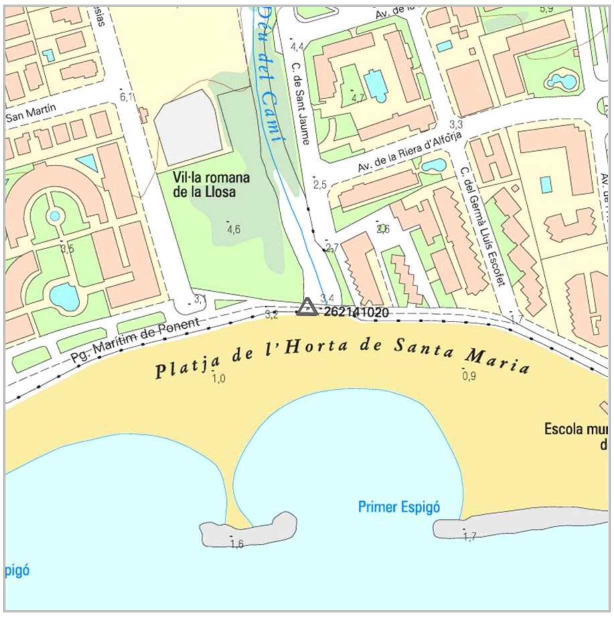
Fotografia

Versió de la fitxa: 20180.180717

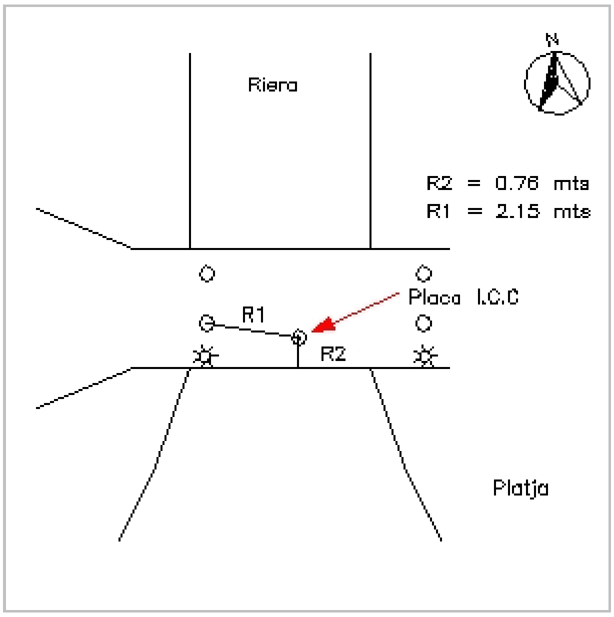
Estat de conservació del vèrtex

Destruït (el vèrtex ha desaparegut).

Mapa de la zona



Accés / Croquis de la zona

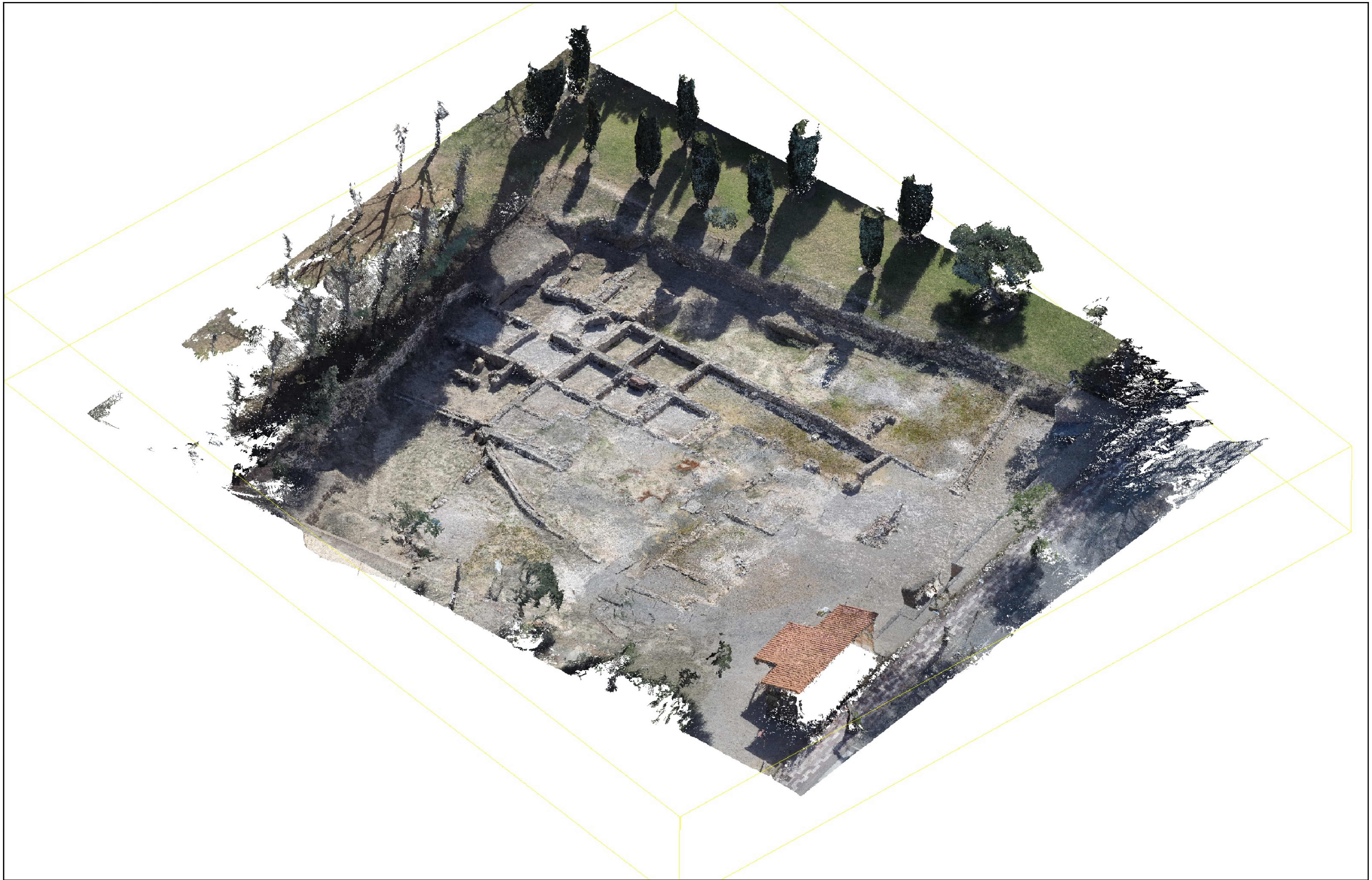


Ubicació del vèrtex

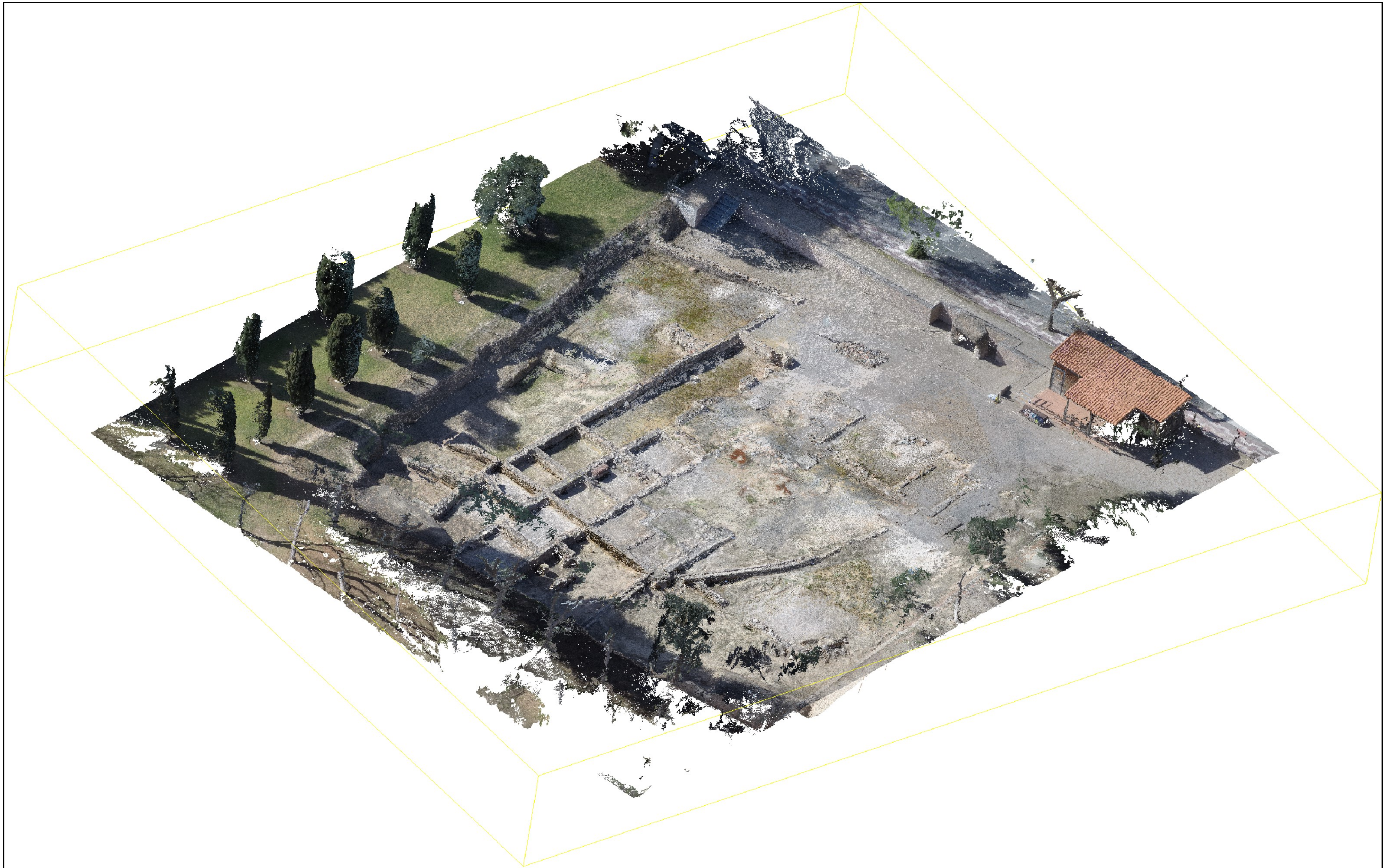
Pont peatonal situat al Passeig Marítim, sobre la riera de Sant Jaume.

Escola Politècnica Superior d'Edificació de Barcelona UNIVERSITAT POLITÈCNICA DE CATALUNYA	Project Title	Projectist: Joaquim Batista Simó	Title of Plane	1 de 8
Grau en Enginyeria en Geoinformació i Geomàtica	Photogrammetric reconstruction of the Roman ruins of Llosa de Cambrils	Director: Felipe Buill Pozuelo	PLAN	Scale: 1 : 225

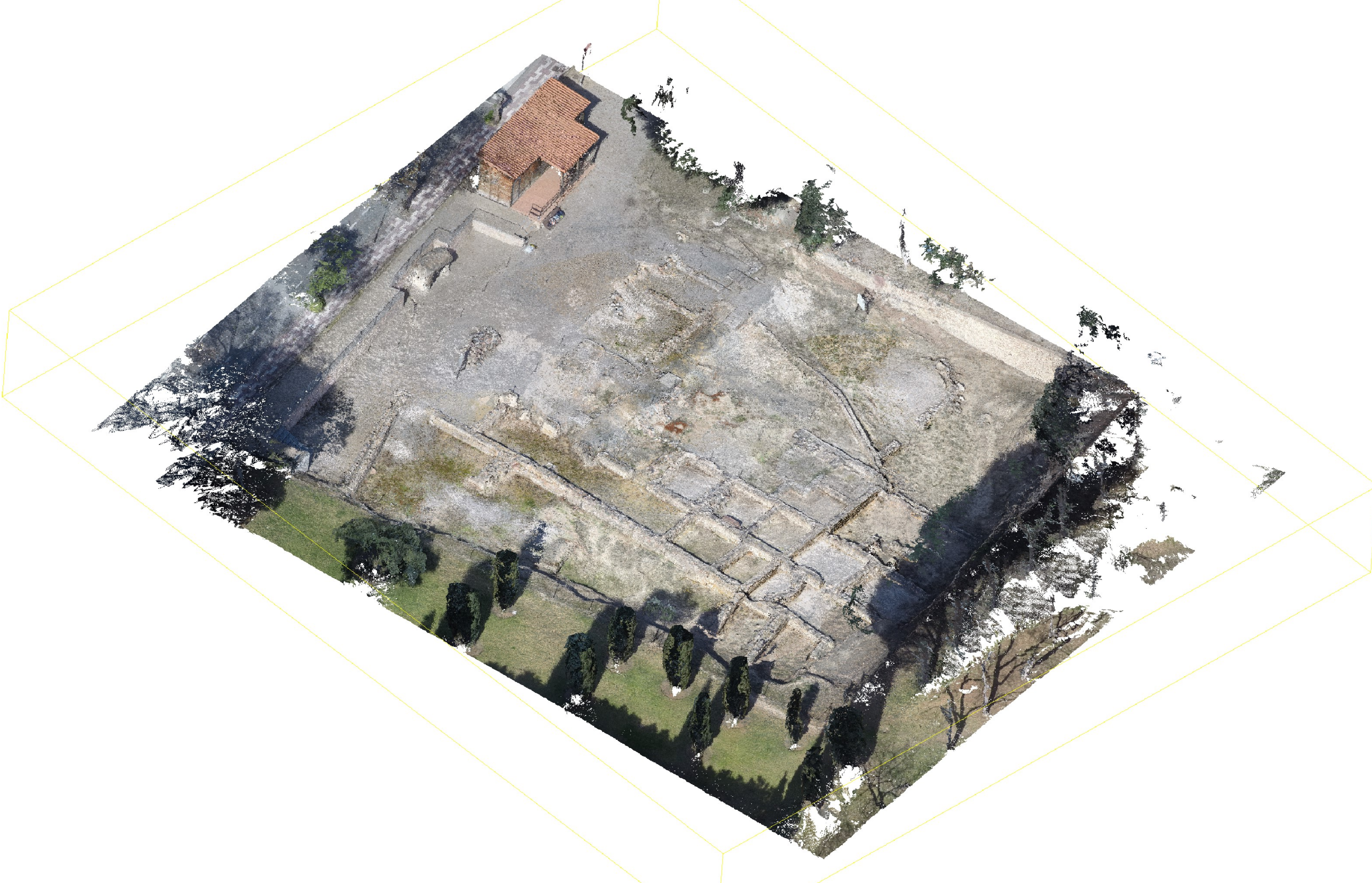
Escola Politècnica Superior d'Edificació de Barcelona UNIVERSITAT POLITÈCNICA DE CATALUNYA	Project Title	Projectist: Joaquim Batista Simó	Title of Plane	2 de 8
Grau en Enginyeria en Geoinformació i Geomàtica	Photogrammetric reconstruction of the Roman ruins of Llosa de Cambrils	Director: Felipe Buill Pozuelo	ISOMETRIC ORTOPHOTOGRAPHY	Scale: 1 : 300



Escola Politècnica Superior d'Edificació de Barcelona UNIVERSITAT POLITÈCNICA DE CATALUNYA	Project Title	Projectist: Joaquim Batista Simó	Title of Plane	3 de 8
Grau en Enginyeria en Geoinformació i Geomàtica	Photogrammetric reconstruction of the Roman ruins of Llosa de Cambrils	Director: Felipe Buill Pozuelo	ISOMETRIC ORTOPHOTOGRAPHY	Scale: 1 : 300



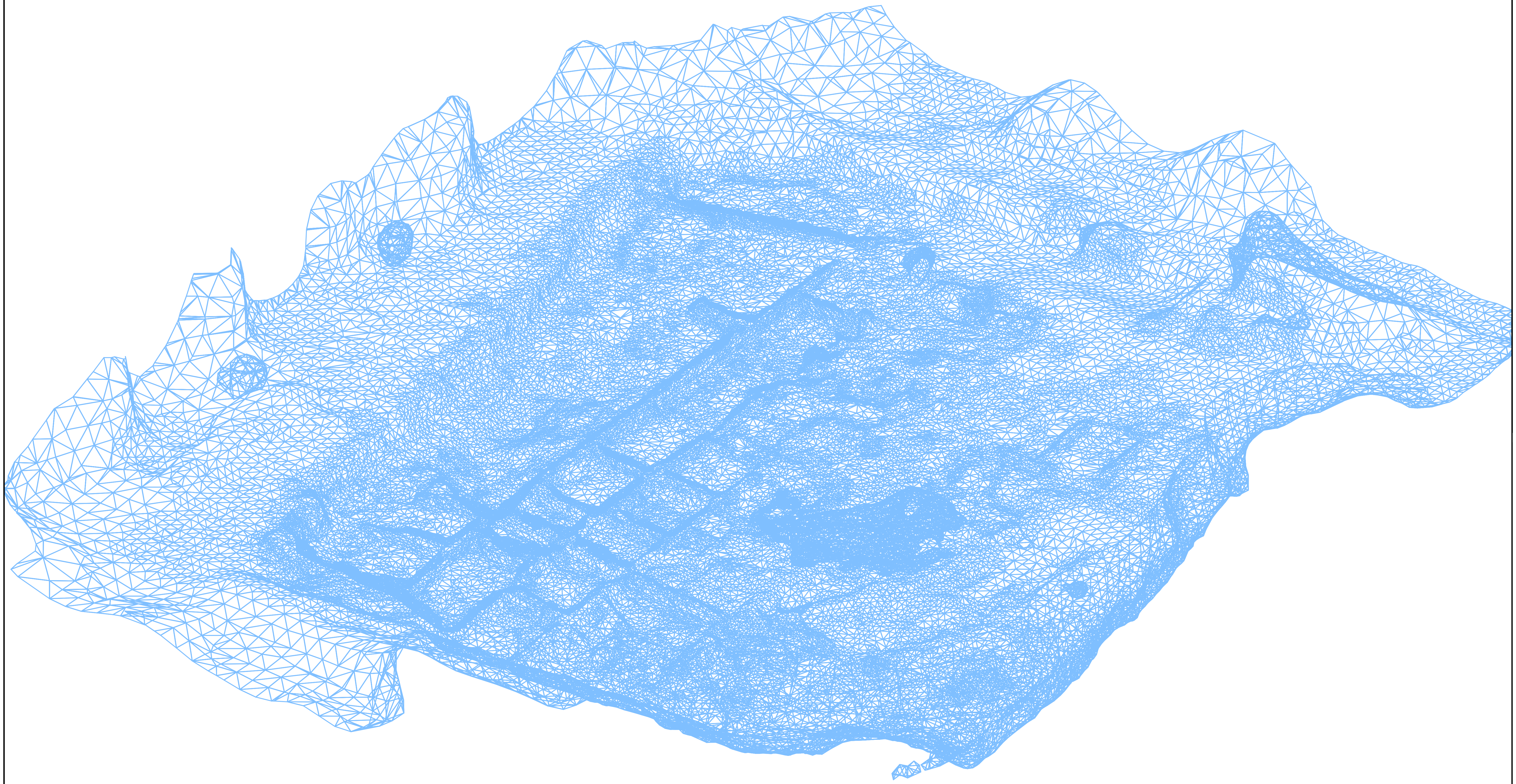
Escola Politècnica Superior d'Edificació de Barcelona UNIVERSITAT POLITÈCNICA DE CATALUNYA	Project Title	Projectist: Joaquim Batista Simó	Title of Plane	4 de 8
Grau en Enginyeria en Geoinformació i Geomàtica	Photogrammetric reconstruction of the Roman ruins of Llosa de Cambrils	Director: Felipe Buill Pozuelo	ISOMETRIC ORTOPHOTOGRAPHY	Scale: 1 : 300



Escola Politècnica Superior d'Edificació de Barcelona UNIVERSITAT POLITÈCNICA DE CATALUNYA	Project Title	Projectist: Joaquim Batista Simó	Title of Plane	5 de 8
Grau en Enginyeria en Geoinformació i Geomàtica	Photogrammetric reconstruction of the Roman ruins of Llosa de Cambrils	Director: Felipe Buill Pozuelo	ISOMETRIC ORTOPHOTOGRAPHY	Scale: 1 : 300

Escola Politècnica Superior d'Edificació de Barcelona UNIVERSITAT POLITÈCNICA DE CATALUNYA	Project Title	Projectist: Joaquim Batista Simó	Title of Plane	6 de 8
Grau en Enginyeria en Geoinformació i Geomàtica	Photogrammetric reconstruction of the Roman ruins of Llosa de Cambrils	Director: Felipe Buill Pozuelo	PROFILE A	Scale: 1 : 200

Escola Politècnica Superior d'Edificació de Barcelona UNIVERSITAT POLITÈCNICA DE CATALUNYA	Project Title	Projectist: Joaquim Batista Simó	Title of Plane	7 de 8
Grau en Enginyeria en Geoinformació i Geomàtica	Photogrammetric reconstruction of the Roman ruins of Llosa de Cambrils	Director: Felipe Buill Pozuelo	PROFILE B	Scale: 1 : 150

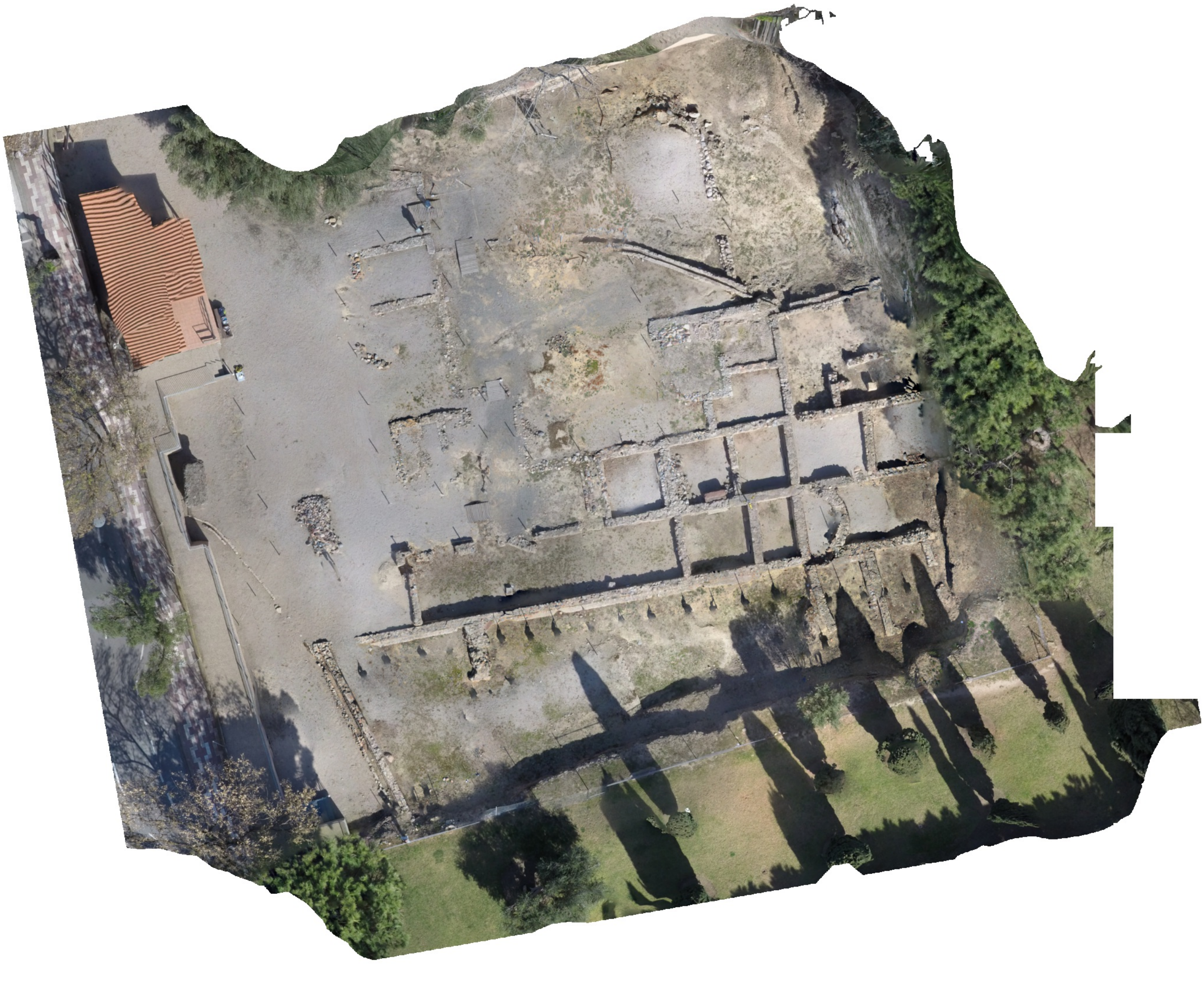


Escola Politècnica Superior d'Edificació de Barcelona UNIVERSITAT POLITÈCNICA DE CATALUNYA	Project Title	Projectist: Joaquim Batista Simó	Title of Plane	8 de 8
Grau en Enginyeria en Geoinformació i Geomàtica	Photogrammetric reconstruction of the Roman ruins of Llosa de Cambrils	Director: Felipe Buill Pozuelo	Model	Scale: 1 : 200

Vil·la Romana de la Llosa

Processing Report

10 September 2019



Survey Data

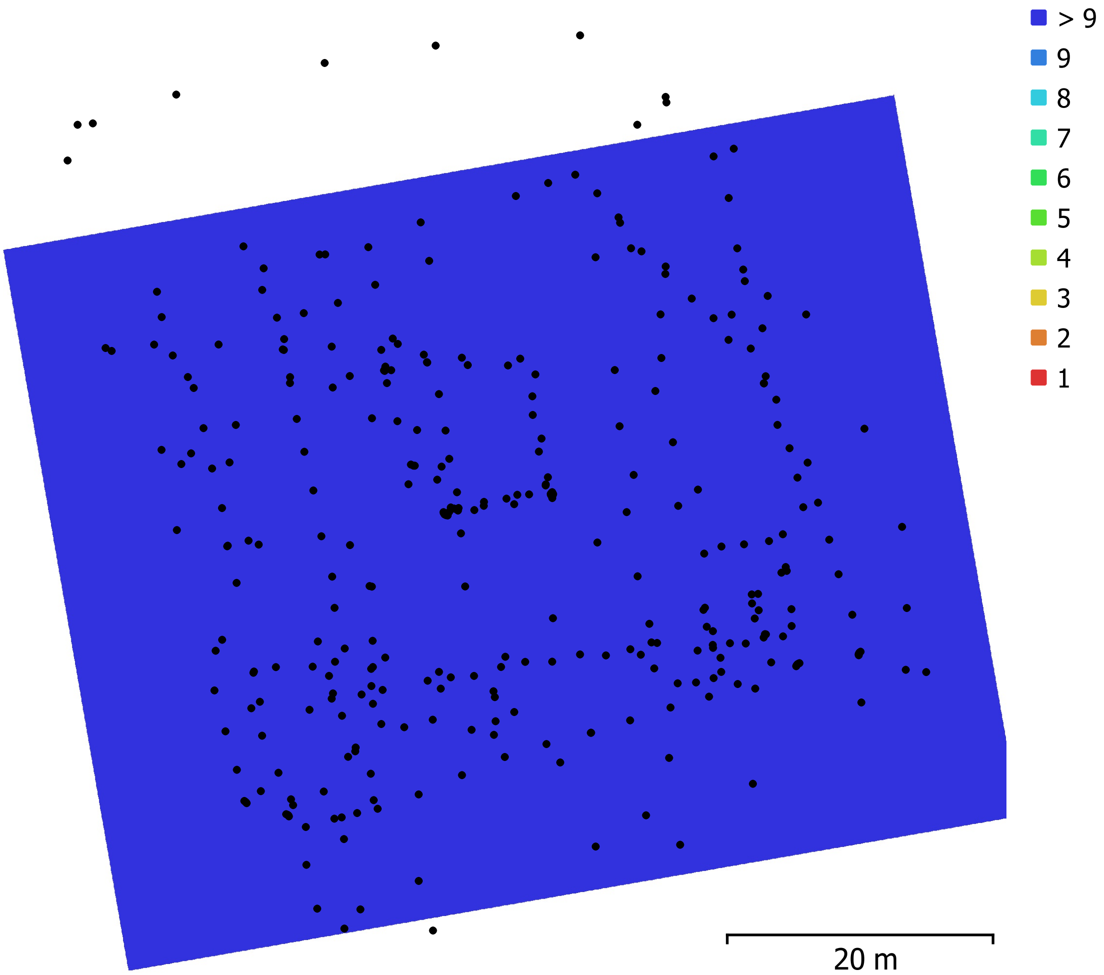


Fig. 1. Camera locations and image overlap.

Number of images:	373	Camera stations:	330
Flying altitude:	14.9 m	Tie points:	286,768
Ground resolution:	3.37 mm/pix	Projections:	683,556
Coverage area:	3.74e+03 m²	Reprojection error:	0.484 pix

Camera Model	Resolution	Focal Length	Pixel Size	Precalibrated
NIKON D5300 (18mm)	6000 x 4000	18 mm	4 x 4 μm	No
HERO4 Black (3mm)	4000 x 3000	3 mm	1.73 x 1.73 μm	No
NIKON D90 (18mm)	4288 x 2848	18 mm	5.6 x 5.6 μm	No

Table 1. Cameras.

Camera Calibration

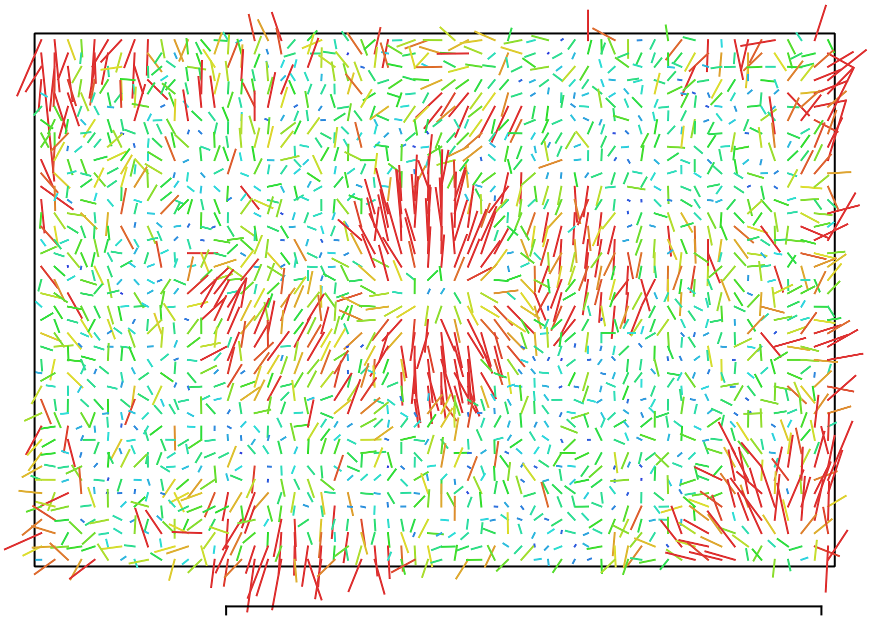


Fig. 2. Image residuals for NIKON D5300 (18mm).

NIKON D5300 (18mm)

145 images

Type	Resolution	Focal Length	Pixel Size
Frame	**6000 x 4000**	**18 mm**	**4 x 4 µm**

	Value	Error	F	Cx	Cy	B1	B2	K1	K2	K3	P1	P2
F	**4728**	0.11	1.00	0.44	-0.74	0.25	0.28	-0.03	0.10	-0.08	0.14	-0.24
Cx	**-20.6333**	0.096		1.00	-0.40	0.29	0.29	0.01	-0.00	0.01	0.74	0.05
Cy	**-48.5313**	0.18			1.00	-0.69	-0.57	-0.04	0.03	-0.03	0.01	0.01
B1	**1.64677**	0.05				1.00	0.62	-0.07	-0.03	0.03	-0.04	0.59
B2	**1.5148**	0.034					1.00	-0.07	0.00	0.00	-0.29	0.44
K1	**-0.0986349**	4e-05						1.00	-0.95	0.90	0.03	-0.21
K2	**0.0307057**	0.00014							1.00	-0.98	0.01	0.05
K3	**-0.00594686**	0.00016								1.00	-0.00	-0.05
P1	**5.65923e-05**	4.2e-06									1.00	-0.14
P2	**-0.00029925**	4.6e-06										1.00

Table 2. Calibration coefficients and correlation matrix.

Camera Calibration

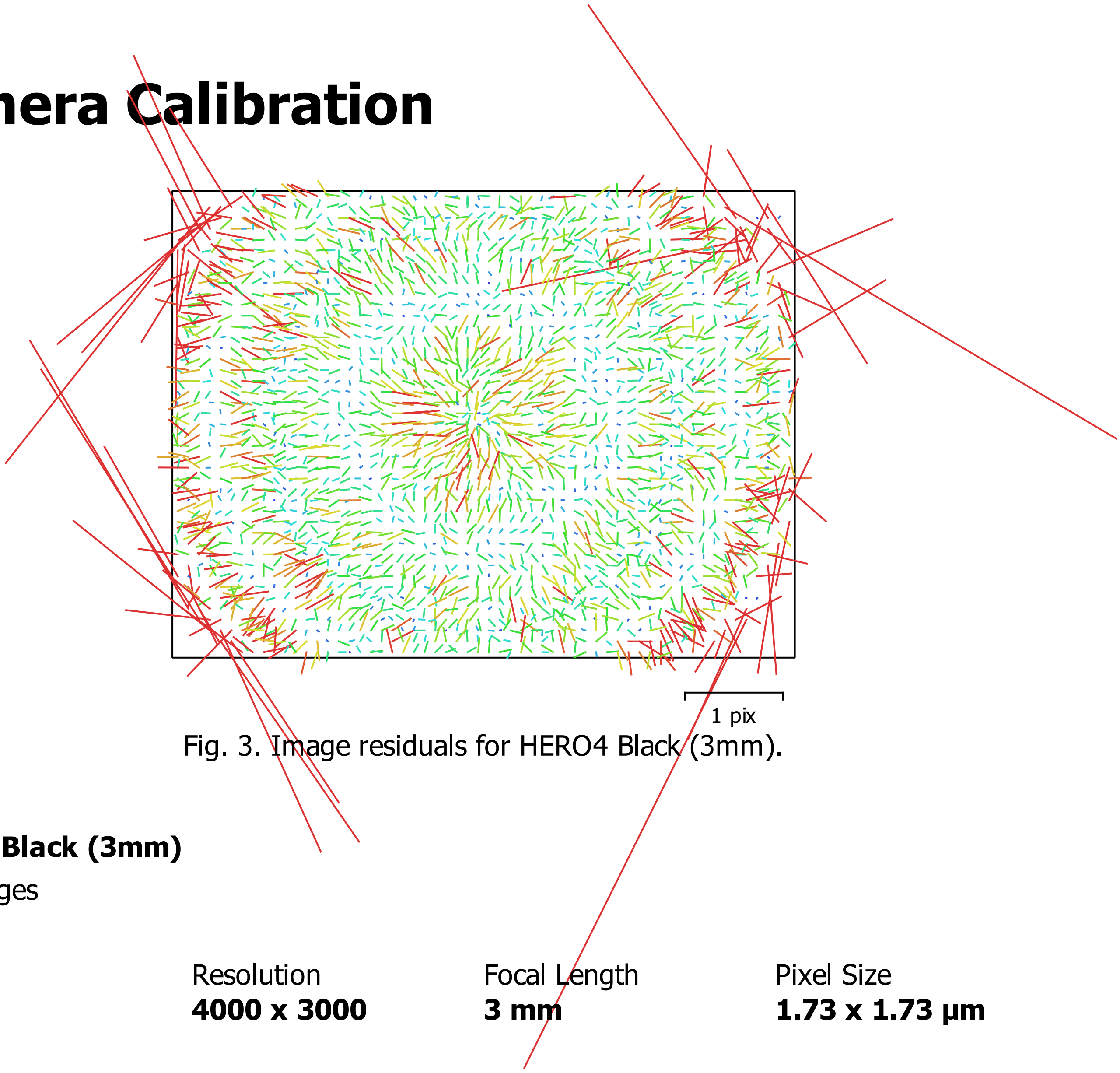


Fig. 3. Image residuals for HERO4 Black (3mm).

HERO4 Black (3mm)
104 images

Type	Resolution	Focal Length	Pixel Size
Frame	**4000 x 3000**	**3 mm**	**1.73 x 1.73 µm**

	Value	Error	F	Cx	Cy	B1	B2	K1	K2	K3	K4	P1	P2
F	**1758.05**	0.14	1.00	0.50	-0.44	0.04	-0.01	-0.72	0.62	-0.57	0.54	-0.25	0.24
Cx	**-61.8658**	0.044		1.00	-0.26	-0.12	0.22	-0.22	0.21	-0.21	0.21	-0.43	0.13
Cy	**-5.88027**	0.041			1.00	-0.22	-0.24	0.22	-0.20	0.19	-0.19	0.12	-0.59
B1	**-1.44388**	0.0084				1.00	0.03	-0.05	0.03	-0.02	0.02	0.18	0.25
B2	**-0.333042**	0.0086					1.00	0.01	-0.03	0.02	-0.02	-0.28	0.31
K1	**-0.253486**	4.4e-05						1.00	-0.95	0.88	-0.83	0.28	-0.25
K2	**0.0866661**	4.1e-05							1.00	-0.98	0.95	-0.16	0.14
K3	**-0.0192258**	1.7e-05								1.00	-0.99	0.13	-0.11
K4	**0.00179472**	2.4e-06									1.00	-0.12	0.10
P1	**4.58276e-05**	1.9e-06										1.00	-0.30
P2	**-0.000121928**	2.1e-06											1.00

Table 3. Calibration coefficients and correlation matrix.

Camera Calibration

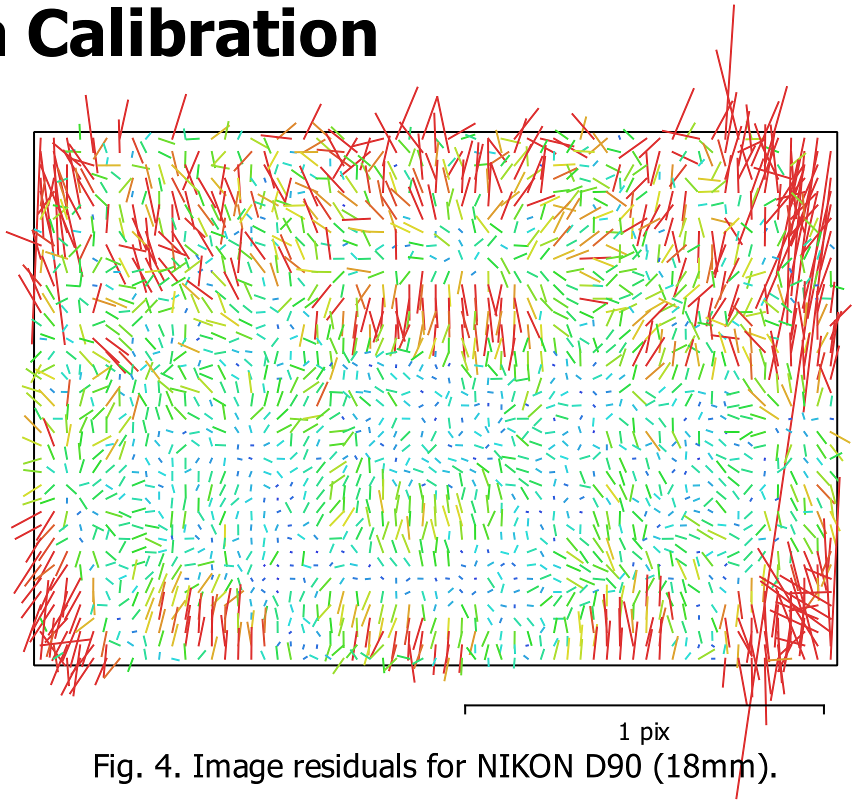


Fig. 4. Image residuals for NIKON D90 (18mm).

NIKON D90 (18mm)

124 images

Type	Resolution	Focal Length	Pixel Size
Frame	**4288 x 2848**	**18 mm**	**5.6 x 5.6 μm**

	Value	Error	F	Cx	Cy	B1	K1	K2	K3	P1	P2
F	**3416.56**	0.31	1.00	0.03	0.40	-0.96	-0.05	0.07	-0.00	0.04	-0.38
Cx	**-66.1557**	0.073		1.00	-0.05	-0.02	0.11	-0.13	0.16	0.94	-0.02
Cy	**64.9541**	0.11			1.00	-0.47	-0.01	0.01	-0.00	-0.04	-0.09
B1	**-22.2026**	0.3				1.00	0.06	-0.03	-0.01	-0.03	0.47
K1	**-0.173907**	6.4e-05					1.00	-0.96	0.92	0.11	0.04
K2	**0.180002**	0.00027						1.00	-0.98	-0.12	-0.03
K3	**-0.0286678**	0.00033							1.00	0.15	0.02
P1	**-0.000336459**	5.3e-06								1.00	-0.01
P2	**-0.000556847**	7.7e-06									1.00

Table 4. Calibration coefficients and correlation matrix.

Ground Control Points

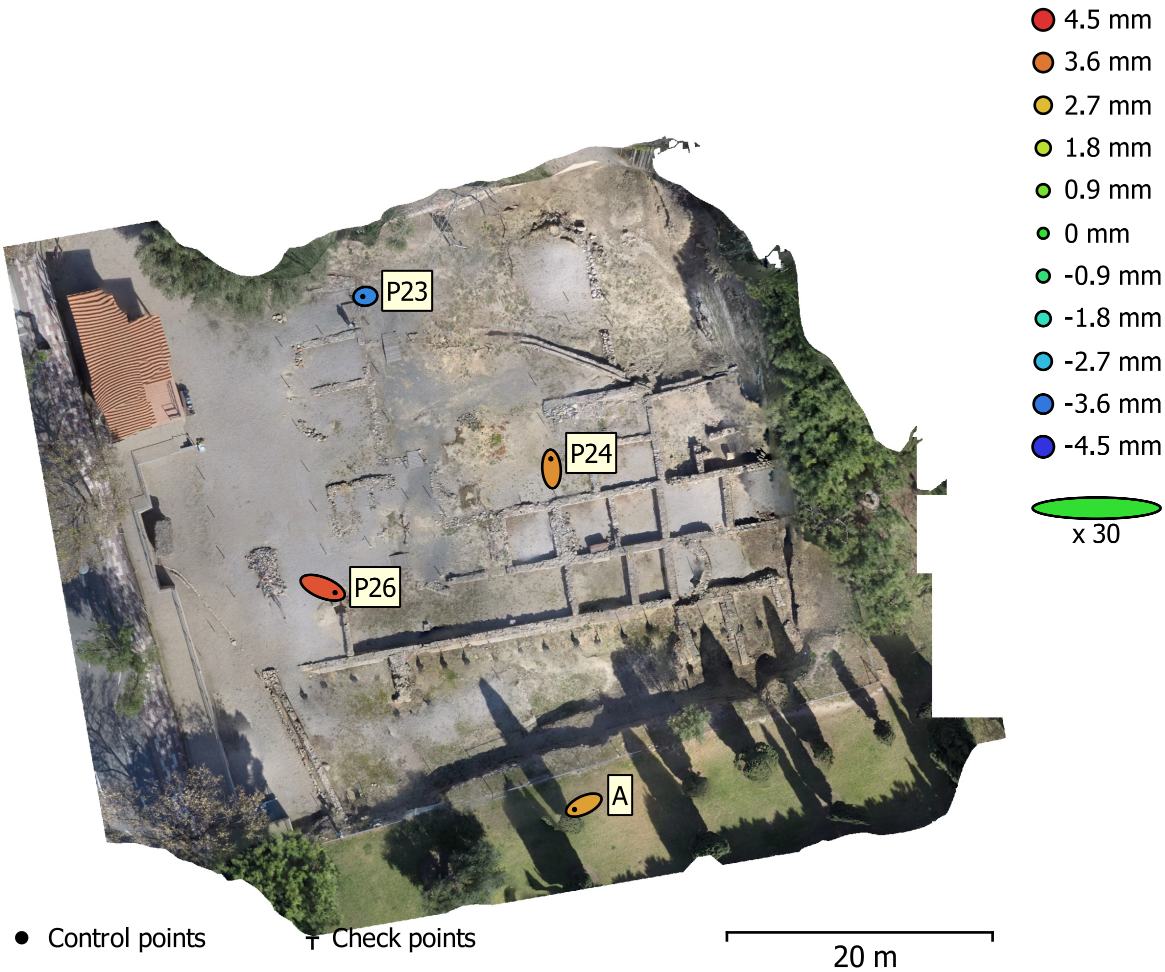


Fig. 5. GCP locations and error estimates.
Z error is represented by ellipse color. X,Y errors are represented by ellipse shape.
Estimated GCP locations are marked with a dot or crossing.

Count	X error (cm)	Y error (cm)	Z error (cm)	XY error (cm)	Total (cm)
4	3.93349	3.02468	0.347336	4.96196	4.9741

Table 5. Control points RMSE.

Label	X error (cm)	Y error (cm)	Z error (cm)	Total (cm)	Image (pix)
P26	6.20344	-2.47351	0.407164	6.69079	0.348 (2)
A	-4.64511	-2.20162	0.305548	5.14952	1.006 (3)
P23	-1.30874	-0.134537	-0.340609	1.35901	2.487 (2)
P24	-0.342051	5.06075	0.327738	5.08288	34.606 (6)
Total	**3.93349**	**3.02468**	**0.347336**	**4.9741**	**23.536**

Table 6. Control points.

Digital Elevation Model

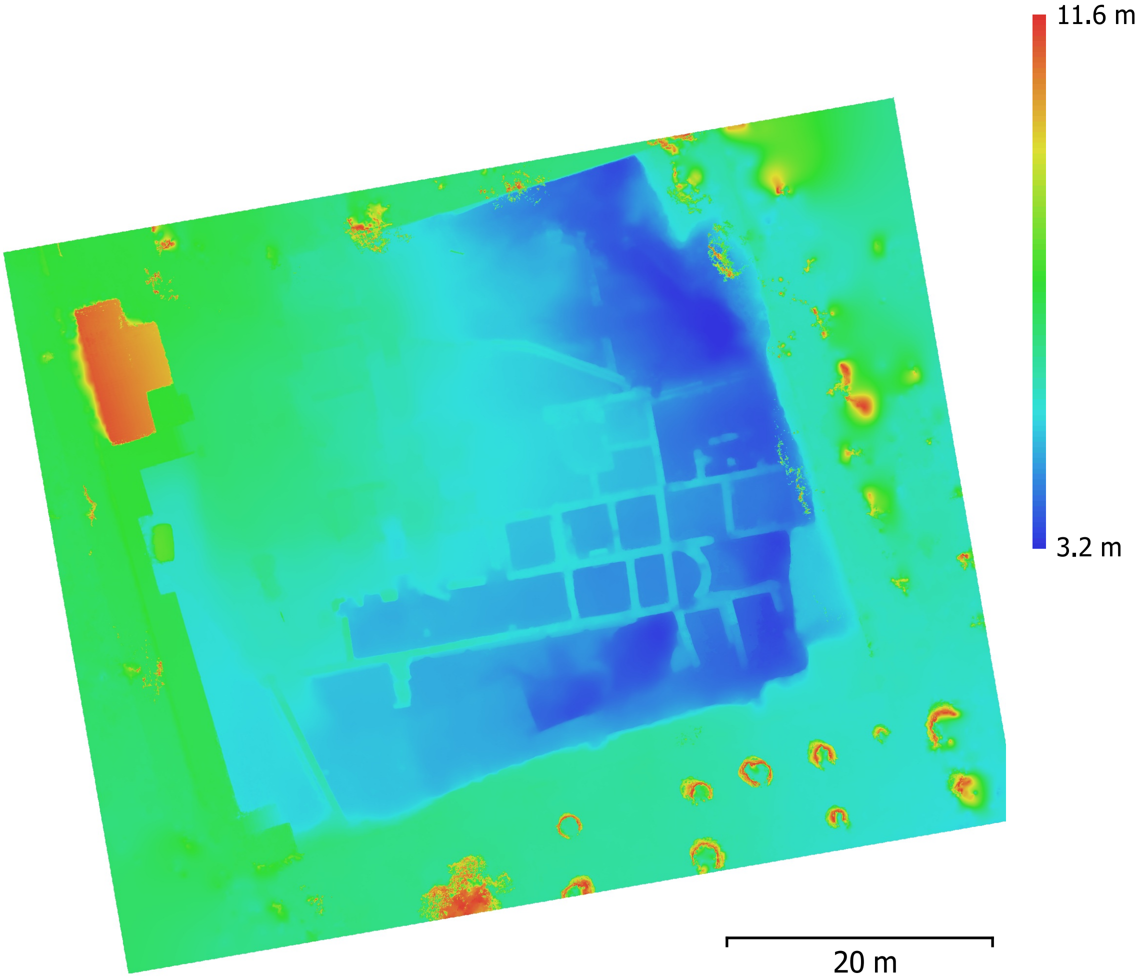


Fig. 6. Reconstructed digital elevation model.

Resolution:	6.74 mm/pix
Point density:	220 points/cm²

Processing Parameters

General	
Cameras	373
Aligned cameras	330
Markers	4
Coordinate system	Local Coordinates (m)
Rotation angles	Yaw, Pitch, Roll
Point Cloud	
Points	286,768 of 410,968
RMS reprojection error	0.0948065 (0.484409 pix)
Max reprojection error	0.326938 (24.8343 pix)
Mean key point size	3.43066 pix
Point colors	3 bands, uint8
Key points	No
Average tie point multiplicity	2.82409
Alignment parameters	
Accuracy	High
Generic preselection	Yes
Key point limit	20,000
Tie point limit	5,000
Adaptive camera model fitting	Yes
Matching time	52 minutes 51 seconds
Alignment time	11 minutes 46 seconds
Dense Point Cloud	
Points	83,814,402
Point colors	3 bands, uint8
Reconstruction parameters	
Quality	High
Depth filtering	Aggressive
Depth maps generation time	4 hours 6 minutes
Dense cloud generation time	22 hours 42 minutes
Model	
Faces	89,999
Vertices	45,221
Vertex colors	3 bands, uint8
Texture	4,096 x 4,096, 4 bands, uint8
Reconstruction parameters	
Surface type	Arbitrary
Source data	Sparse
Interpolation	Enabled
Face count	90,000
Processing time	6 seconds
Texturing parameters	
Mapping mode	Generic
Blending mode	Mosaic
Texture size	4,096 x 4,096
Enable hole filling	Yes
Enable ghosting filter	Yes
UV mapping time	33 seconds
Blending time	30 minutes 25 seconds
Tiled Model	
Texture	3 bands, uint8
Reconstruction parameters	
Source data	Dense cloud
Tile size	1024
Enable ghosting filter	No

Processing time	3 hours 21 minutes
DEM	
Size	11,353 x 9,787
Coordinate system	Local Coordinates (m)
Reconstruction parameters	
Source data	Dense cloud
Interpolation	Enabled
Processing time	58 seconds
Orthomosaic	
Size	22,410 x 17,860
Coordinate system	Local Coordinates (m)
Colors	3 bands, uint8
Reconstruction parameters	
Blending mode	Mosaic
Surface	Mesh
Enable hole filling	Yes
Processing time	13 minutes 30 seconds
Software	
Version	1.4.3 build 6529
Platform	Windows 64

Registration Report

Project	VilaRomana
Cluster	Scans
Recording Period	1/1/2002, 12:08:51 AM - 1/1/2002, 1:49:38 AM
Location	
Report Date	8/8/2019, 8:06:44 AM

Color Coding

Point Error	< 8 mm	> 20 mm
Overlap	> 25.0 %	< 10.0 %

Overview

Scan Point Statistics

Maximum Point Error	6.3 mm
Mean Point Error	3.8 mm
Minimum Overlap	30.9 %

Scan Errors

Scan Point Statistics

Cluster/Scan	Connections	Max. Point Error [mm]	Mean Point Error [mm]	Min. Overlap
Trimble_Scan_075	4	4.1	3.3	54.5 %
Trimble_Scan_076	11	6.2	4.2	52.3 %
Trimble_Scan_077	13	6.3	4.7	30.9 %
Trimble_Scan_078	6	4.7	3.8	59.5 %
Trimble_Scan_079	6	6.2	4.4	52.3 %
Trimble_Scan_080	5	5.8	3.9	54.6 %
Trimble_Scan_081	5	6.3	4.0	46.1 %
Trimble_Scan_082	4	4.1	3.7	71.2 %
Trimble_Scan_083	4	4.3	3.6	71.4 %
Trimble_Scan_084	5	4.9	3.6	53.6 %
Trimble_Scan_085	4	3.1	2.7	71.4 %
Trimble_Scan_086	5	4.3	3.2	72.5 %
Trimble_Scan_087	4	4.9	3.2	66.4 %
Trimble_Scan_088	5	4.6	3.5	72.5 %
Trimble_Scan_089	8	4.1	3.3	64.4 %
Trimble_Scan_090	8	5.3	3.8	53.2 %
Trimble_Scan_091	7	4.0	3.3	64.6 %
Trimble_Scan_092	8	5.7	3.7	45.4 %
Trimble_Scan_093	8	5.8	3.9	48.5 %
Trimble_Scan_094	11	4.3	3.5	50.5 %
Trimble_Scan_073	7	5.3	4.1	30.9 %
Trimble_Scan_074	6	4.9	3.5	38.4 %

Detailed Errors

Scan Point Statistics

Cluster/Scan 1	Cluster/Scan 2	Point Error [mm]	Overlap
Trimble_Scan_075	Trimble_Scan_076	3.2	74.2 %
Trimble_Scan_076	Trimble_Scan_092	3.6	61.3 %
Trimble_Scan_077	Trimble_Scan_076	3.8	69.0 %
Trimble_Scan_077	Trimble_Scan_094	4.3	50.5 %
Trimble_Scan_077	Trimble_Scan_078	3.4	74.9 %
Trimble_Scan_077	Trimble_Scan_092	5.7	45.4 %
Trimble_Scan_077	Trimble_Scan_079	5.2	63.5 %
Trimble_Scan_078	Trimble_Scan_076	4.7	59.5 %
Trimble_Scan_078	Trimble_Scan_094	3.0	82.2 %
Trimble_Scan_078	Trimble_Scan_079	3.3	81.2 %
Trimble_Scan_079	Trimble_Scan_076	6.2	52.3 %
Trimble_Scan_080	Trimble_Scan_077	5.8	54.6 %
Trimble_Scan_080	Trimble_Scan_079	3.6	73.2 %
Trimble_Scan_080	Trimble_Scan_081	3.4	75.5 %
Trimble_Scan_080	Trimble_Scan_094	3.6	77.8 %
Trimble_Scan_081	Trimble_Scan_077	6.3	46.1 %
Trimble_Scan_081	Trimble_Scan_094	4.0	75.3 %
Trimble_Scan_082	Trimble_Scan_081	2.9	88.2 %
Trimble_Scan_082	Trimble_Scan_094	4.1	71.2 %
Trimble_Scan_082	Trimble_Scan_083	4.1	76.4 %
Trimble_Scan_083	Trimble_Scan_084	2.9	88.2 %
Trimble_Scan_083	Trimble_Scan_086	4.3	77.6 %
Trimble_Scan_083	Trimble_Scan_085	3.1	71.4 %
Trimble_Scan_084	Trimble_Scan_086	3.3	78.7 %
Trimble_Scan_084	Trimble_Scan_085	2.5	84.5 %
Trimble_Scan_084	Trimble_Scan_092	4.6	53.6 %
Trimble_Scan_085	Trimble_Scan_086	2.4	86.4 %
Trimble_Scan_087	Trimble_Scan_084	4.9	66.4 %
Trimble_Scan_087	Trimble_Scan_085	2.9	76.6 %
Trimble_Scan_087	Trimble_Scan_086	2.5	87.8 %
Trimble_Scan_087	Trimble_Scan_088	2.4	85.7 %
Trimble_Scan_088	Trimble_Scan_086	3.4	72.5 %
Trimble_Scan_088	Trimble_Scan_092	4.6	74.6 %
Trimble_Scan_089	Trimble_Scan_075	4.1	64.5 %
Trimble_Scan_089	Trimble_Scan_076	3.9	71.9 %

Trimble_Scan_089	Trimble_Scan_077	3.7	64.4 %
Trimble_Scan_089	Trimble_Scan_088	2.8	83.8 %
Trimble_Scan_089	Trimble_Scan_074	2.9	75.8 %
Trimble_Scan_089	Trimble_Scan_073	3.4	77.2 %
Trimble_Scan_090	Trimble_Scan_076	4.6	60.5 %
Trimble_Scan_090	Trimble_Scan_077	4.7	53.2 %
Trimble_Scan_090	Trimble_Scan_089	2.5	89.3 %
Trimble_Scan_090	Trimble_Scan_091	2.5	85.1 %
Trimble_Scan_090	Trimble_Scan_092	2.5	85.7 %
Trimble_Scan_090	Trimble_Scan_074	4.9	63.3 %
Trimble_Scan_090	Trimble_Scan_073	5.3	68.8 %
Trimble_Scan_090	Trimble_Scan_094	3.0	87.0 %
Trimble_Scan_091	Trimble_Scan_076	3.5	69.4 %
Trimble_Scan_091	Trimble_Scan_077	3.4	66.3 %
Trimble_Scan_091	Trimble_Scan_078	4.0	64.6 %
Trimble_Scan_091	Trimble_Scan_089	3.3	76.5 %
Trimble_Scan_091	Trimble_Scan_094	3.1	69.0 %
Trimble_Scan_091	Trimble_Scan_092	3.2	72.9 %
Trimble_Scan_093	Trimble_Scan_077	5.8	48.5 %
Trimble_Scan_093	Trimble_Scan_078	4.5	63.0 %
Trimble_Scan_093	Trimble_Scan_079	4.4	69.2 %
Trimble_Scan_093	Trimble_Scan_080	3.2	79.0 %
Trimble_Scan_093	Trimble_Scan_081	3.3	81.1 %
Trimble_Scan_093	Trimble_Scan_082	3.6	75.6 %
Trimble_Scan_093	Trimble_Scan_092	3.2	78.5 %
Trimble_Scan_093	Trimble_Scan_094	3.0	73.9 %
Trimble_Scan_094	Trimble_Scan_076	3.7	71.9 %
Trimble_Scan_094	Trimble_Scan_079	3.6	75.8 %
Trimble_Scan_094	Trimble_Scan_092	2.6	91.4 %
Trimble_Scan_073	Trimble_Scan_075	3.6	54.5 %
Trimble_Scan_073	Trimble_Scan_076	4.7	60.5 %
Trimble_Scan_073	Trimble_Scan_077	5.0	30.9 %
Trimble_Scan_073	Trimble_Scan_088	4.5	74.4 %
Trimble_Scan_074	Trimble_Scan_075	2.5	72.8 %
Trimble_Scan_074	Trimble_Scan_076	3.8	65.0 %
Trimble_Scan_074	Trimble_Scan_077	4.5	38.4 %
Trimble_Scan_074	Trimble_Scan_073	2.2	83.4 %

Inclinometer Mismatches

Cluster/Scan	Scan	Mismatch [deg]
Trimble_Scan_093	Trimble_Scan_093	0.0124
Trimble_Scan_082	Trimble_Scan_082	0.0070
Trimble_Scan_090	Trimble_Scan_090	0.0093
Trimble_Scan_091	Trimble_Scan_091	0.0121
Trimble_Scan_089	Trimble_Scan_089	0.0135
Trimble_Scan_087	Trimble_Scan_087	0.0088
Trimble_Scan_083	Trimble_Scan_083	0.0175
Trimble_Scan_074	Trimble_Scan_074	0.0127
Trimble_Scan_073	Trimble_Scan_073	0.0158
Trimble_Scan_080	Trimble_Scan_080	0.0057
Trimble_Scan_081	Trimble_Scan_081	0.0066
Trimble_Scan_077	Trimble_Scan_077	0.0039
Trimble_Scan_084	Trimble_Scan_084	0.0031
Trimble_Scan_078	Trimble_Scan_078	0.0080
Trimble_Scan_088	Trimble_Scan_088	0.0134
Trimble_Scan_075	Trimble_Scan_075	0.0165
Trimble_Scan_094	Trimble_Scan_094	0.0104
Trimble_Scan_079	Trimble_Scan_079	0.0028
Trimble_Scan_085	Trimble_Scan_085	0.0112
Trimble_Scan_076	Trimble_Scan_076	0.0037
Trimble_Scan_086	Trimble_Scan_086	0.0045
Trimble_Scan_092	Trimble_Scan_092	0.0006